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RUBINOBS/NSF/DOE/NOIRLAB/SLAC/AURA/W. O'MULLANE

SKAO/MAX ALEXANDER, CC BY 3.0

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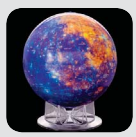

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A monumental year

Medieval clocks like Prague's Orloj stand as monuments to the ingenuity and values of the societies that built them. ALEXANDRA TRAN/UNSPLASH

The year 2025 in astronomy featured a remarkable split-screen: A string of scientific successes and intriguing discoveries were announced while some of the U.S. agencies that funded those achievements were being threatened with massive budget cuts.

Our top story of the year is an example of what investments in science can yield: the opening of the $800 million Vera C. Rubin Observatory, funded by the National Science Foundation and the Department of Energy. Rubin's ability to continuously survey the southern sky will transform our map of the solar system and advance our knowledge of the vastest contours of the cosmos. The decadeslong project is a testament to humanity's ability to not just gaze in wonder upon the night sky, but to study it, to examine it, and to engineer technological marvels to peel back its layers of darkness and shed light on its mysteries.

Elsewhere in this issue, Robert Reeves highlights some of the best NGC star clusters to check out this winter, following his story from our July 2025 issue covering the summer months. These clusters are fantastic targets for visual observers as well as users of smart-scopes like the Celestron Origin, which took the images in the story.

On page 36, Contributing Editor Raymond Shubinski takes us on a tour of Europe's grand celestial clocks, which were commissioned as public works centuries ago by municipal governments. And I had the pleasure of speaking to astrophotographer Josh Dury, whose stunning image of the major lunar standstill over Stonehenge (page 48) captures the art and science of the event.

Perhaps in 400 years, facilities like Rubin will stand as these clocks and Stonehenge do — monuments to their builders' appreciation of the workings of the universe and our efforts to better understand them.

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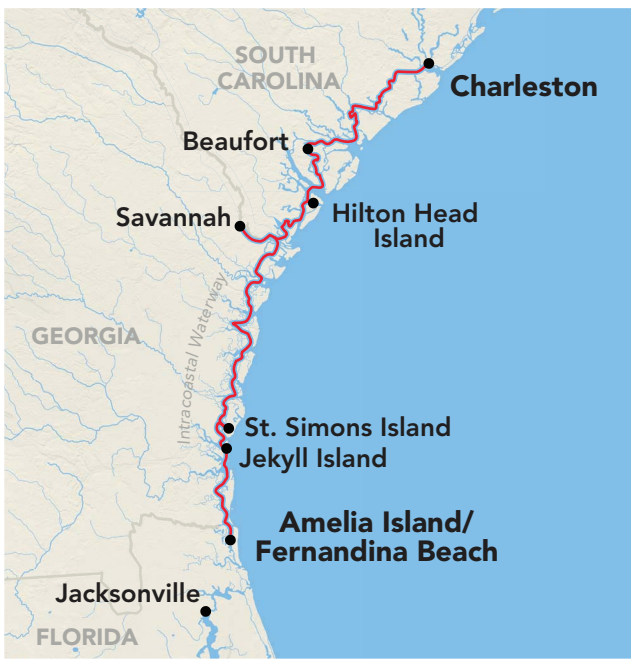

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Comet Hale-Bopp, seen here with the North America Nebula, was brightest in the sky in the spring of 1997. TONY HALLAS

We welcome your comments via email to **astronomyeditorial@astronomy.com**. *Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Eyewitness account

Today I read Donald Goldsmith's article "Why you can't trust your eyes" (September 2025) and appreciated his layman-friendly presentation. As a retired state trooper, I know that eyewitnesses are nearly useless and frequently lead investigators down a fruitless path. It was fun to relearn the science behind the concepts. **—Matthew Leveque,** Knoxville, TN

Starry memories

The article about Comet Hale-Bopp in your October issue brought back happy memories of that event. My father and I took photos using a Nikon F2 with Kodak film behind a Celestron C-6. This was our first attempt at astrophotography. My daughter Allison was born in early May 1997. We kept a picture of Hale-Bopp, with our house in the foreground, in her room. We told her that she came to us on the comet and was a gift from the stars. **—Frederick S. Black,** Sea Cliff, NY

Elemental writing

I want to commend Molly Wakefield on her outstanding article "The story of the elements" from the October 2025 issue. She provided an excellent simplified explanation of how the elements came to be. This was the first time I have seen it explained. I am not a chemistry man, but I could get the gist of it. Also, her monthly Observing Basics column is always informative and a must read. Keep up the good work. I am a fan. **—Carl Rutter,** Fontana, CA

Erratum

The description of No. 34 in our "Star Products" (October 2025) contained a few inaccuracies. The correct details are as follows: Wood Wonders Eyepiece Cases are available in one- or two-drawer versions with multiple layout possibilities for 1.25- and 2-inch barrels. They feature elegant hardwood with a protective finish, quality brass hardware, and dimmable red LED lighting that activates when the lid opens. Cases come in two sizes, 14.5 x 10 x 9 inches (36.8 x 25.4 x 22.9 centimeters) and 20 x 10 x 9 inches (50.8 x 25.4 x 22.9 cm). Options include custom stains, 3D celestial carvings, antifog heating pads, customer-designed eyepiece layouts, and more. Visit wood-wonders.com.

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SNAPSHOT

WEBB CATCHES THE SPIDER

Infrared view shows new detail in a glowing planetary nebula.

NGC 6537 is a planetary nebula with a second name: the Red Spider Nebula. The apt moniker calls attention to the object's hourglass shape, with a glowing red body and spindly legs. This is a planetary nebula, created during the last stages of a Sun-like star's life. It is lit by a white dwarf — the leftover, cooling core of the star — at the center. An unseen companion star may be further shaping the narrow nebula.

This image from the James Webb Space Telescope's NIRCam instrument shows the Red Spider in unprecedented detail. The infrared view uncovered a previously hidden disk of hot dust around the star, within the Spider's body. An S-shaped jet curls out from the center, sculpting the nebula as it expands. And visible for the first time is the full extent of the lobes forming the legs, each 3 light-years long.

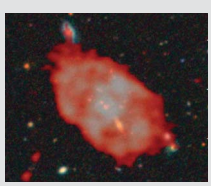
Planetary nebulae are a fleeting phase in a star's life, lasting only a few tens of thousands of years before fading away. —ALISON KLESMAN

ESA/WEBB, NASA & CSA, J. H. KASTNER (ROCHESTER INSTITUTE OF TECHNOLOGY). BOTTOM FROM LEFT: NASA/KEEGAN BARBER; RAD@HOME ASTRONOMY COLLABORATORY (INDIA) (CC BY 4.0); NASA/JPL

HOT BYTES

RESET THE CLOCK

A study combining citizen science and machine learning found the April 2024 total solar eclipse "reset" birds' biological clocks, prompting them to act as if dawn had broken anew as the Sun emerged from totality.



STRANGE RINGS

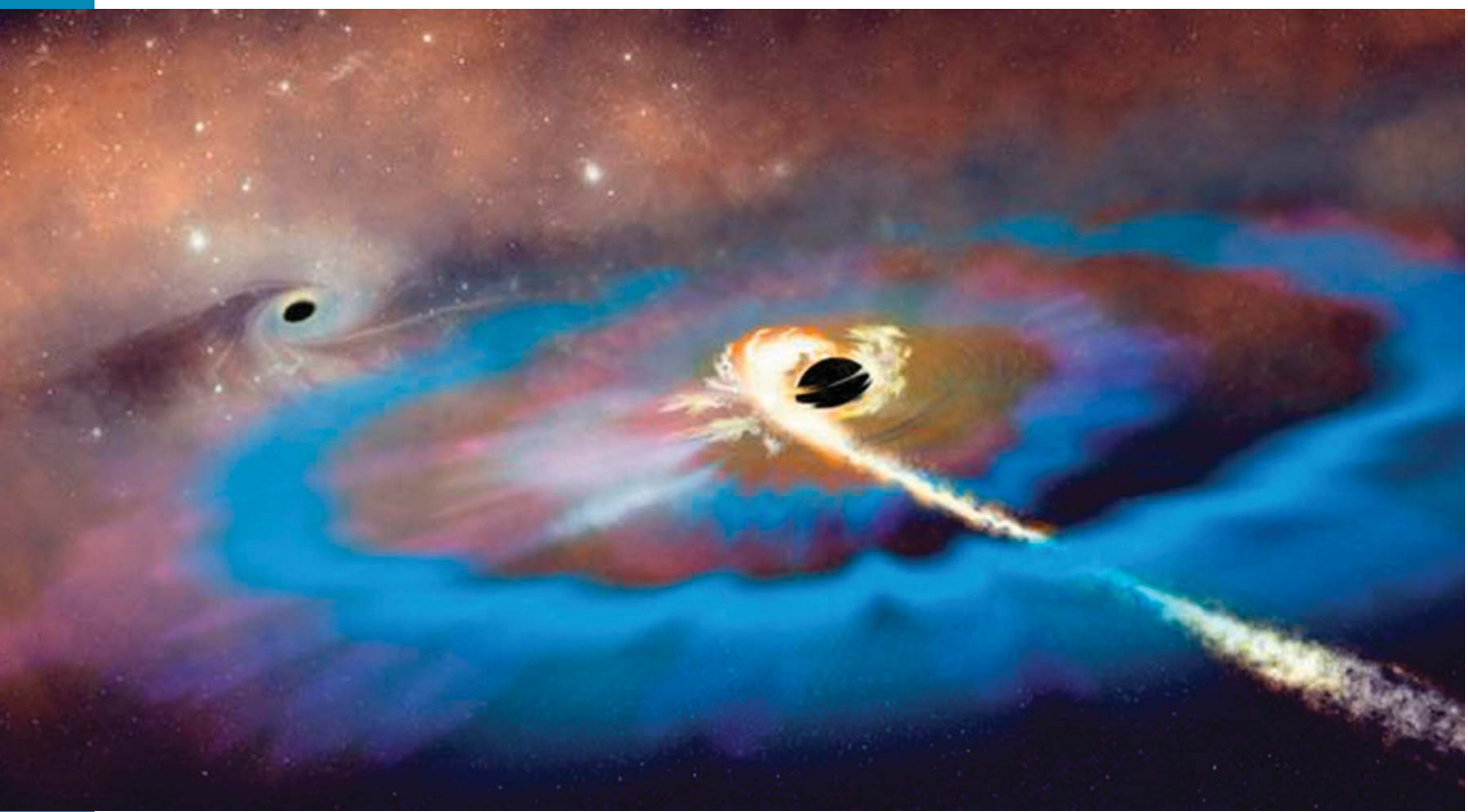
Astronomers have discovered the most distant and powerful odd radio circle (ORC) to date, comprising two intersecting rings of radio emission surrounding a single galaxy. ORCs are thought to arise when galaxies or supermassive black holes merge.

NASA LAYOFFS

On Oct. 13, NASA's Jet Propulsion Laboratory announced it would lay off 550 workers. JPL director Dave Gallagher said the move was part of a planned reorganization unrelated to the then-ongoing government shutdown.

BLACK HOLE SEEN SNACKING FAR FROM HOST GALAXY'S CENTER

Astronomers are wondering why this supermassive black hole is 2,600 light-years from where it's supposed to be.



UNEXPECTED GUEST. A supermassive black hole far from its galaxy's center tears apart a star in the foreground of this artist's rendition, creating a tidal disruption event. In the background is a second supermassive black hole located in the center of the host galaxy, as expected. NSF/AUI/NSF NRAO/P.VOSTEEN

For the first time, astronomers have detected intense, fast-changing radio signals as a supermassive black hole tears apart a star, far from its galaxy's core. Now researchers are trying to understand why the black hole is 2,600 light-years from where they expect it to be, what its strange signals mean, and whether there are more unseen giants hidden across the cosmos.

The discovery was published Oct. 13 in *The Astrophysical Journal Letters*.

INTRUDER ALERT

Supermassive black holes anchor nearly every large galaxy. They are generally quiet, but occasionally a star wanders too close and is ripped to shreds. The stellar debris heats up as it spirals inward, producing intense radiation. Astronomers have seen around 200 of these so-called tidal disruption events (TDEs). But until now, they always occurred in the center of a galaxy, where supermassive black holes typically reside.

This TDE, dubbed AT2024tvd and spotted by the Zwicky Transient Facility, which scans the sky for sudden flashes, looked unremarkable — until follow-up observations revealed its off-center location.

There is already a known supermassive black hole located in the middle of AT2024tvd's host galaxy. And study lead author Itai Sfaradi, a postdoctoral researcher at the University of California-Berkeley, says the fact that AT2024tvd was deflected so far from the galaxy's core may imply that there's even a *third* supermassive black hole lurking in the galaxy, as combined interactions with two other massive

black holes could have been responsible for flinging AT2024tvd's black hole away.

Astronomers have speculated for years that mergers can sling supermassive black holes to the outer regions of galaxies. But only a handful have ever been seen there. AT2024tvd may be the clearest confirmation yet of this idea. Sfaradi says the black hole that unleashed AT2024tvd was likely either flung outward when the host galaxy merged with one or more other galaxies, or originated in a different galaxy that merged with another to form the current one. "The questions of how they came to be in a triplet or where the third one is are very good, but we don't have a good understanding of that yet," Sfaradi tells *Astronomy*.

RADIO RACKET

Follow-up observations also revealed two powerful radio outbursts, 131 days and 194 days after discovery. It only takes hours for a supermassive black hole to shred a star. But black holes aren't tidy eaters. They can emit outflows that create shock waves, which then produce radio emission when they slam into surrounding gas. That can happen soon after the star disintegrates or months later.

"What's exciting about this one is how well-sampled the data are," says study co-author Yvette Cendes, an assistant professor at the University of Oregon. "We've seen second brightenings before, but this time we watched the rise and fall in real time."

It's unclear whether AT2024tvd's bursts are two separate outflows, or one outflow colliding with more gas around the black hole later on.

Ultimately, the discovery may encourage researchers to rethink the search for TDEs. Surveys have focused on galactic centers, assuming that's where the action is. But now that an off-center TDE has been spotted, astronomers may focus their efforts outward and find more, says Cendes.

"It's clear that the picture is more complex than we thought, which is both frustrating and fun," Cendes says.
– ASHLEY BALZER VIGIL

TEAM TUMBLEWEED/SAS SCHILTEN, CC BY-SA

Rover goes for a spin

Last April at a quarry in the Netherlands, researchers tested a prototype of a unique rover dubbed Tumbleweed: a spherical, 8.8-foot-diameter (2.7 meters) robot designed to roll across Mars, powered only by wind. Previously tested in a wind tunnel at Aarhus University, this field campaign in Maastricht confirmed the rover's ability to gather data while tumbling over uneven natural terrain. The final rovers will be 16.4-foot (5 m) spheres, powered entirely by martian winds. Team Tumbleweed and the European Space Agency aim to deploy a swarm of these rovers by 2034. By rolling from the poles to the equator, the rovers will create a low-cost, long-range sensor network to map the planet and search for underground water ice. – BROOKS MENDENHALL

QUICK TAKES

SECOND CHANCE

On Nov. 4, President Donald Trump once again nominated private astronaut and entrepreneur Jared Isaacman for NASA administrator, five months after withdrawing his candidacy amid a public rift with Isaacman supporter and SpaceX CEO Elon Musk.

PLENTIFUL PHOSPHINE

JWST has found that the outer layers of brown dwarf Wolf 1130C have more phosphine than expected, researchers reported Oct. 2 in *Science*. The disputed detection of phosphine on Venus in 2021 cast the molecule as a potential biosignature, but its abundance in Wolf 1130C — a "failed star" — leads the team to caution against that interpretation.

COLD STORAGE

E. coli amino acids could survive 50 million years of radiation if preserved in martian ice, according to NASA and Penn State experiments and modeling. Samples in Mars-like soil degraded 10 times faster, suggesting future life-detection missions to the Red Planet should target ice.

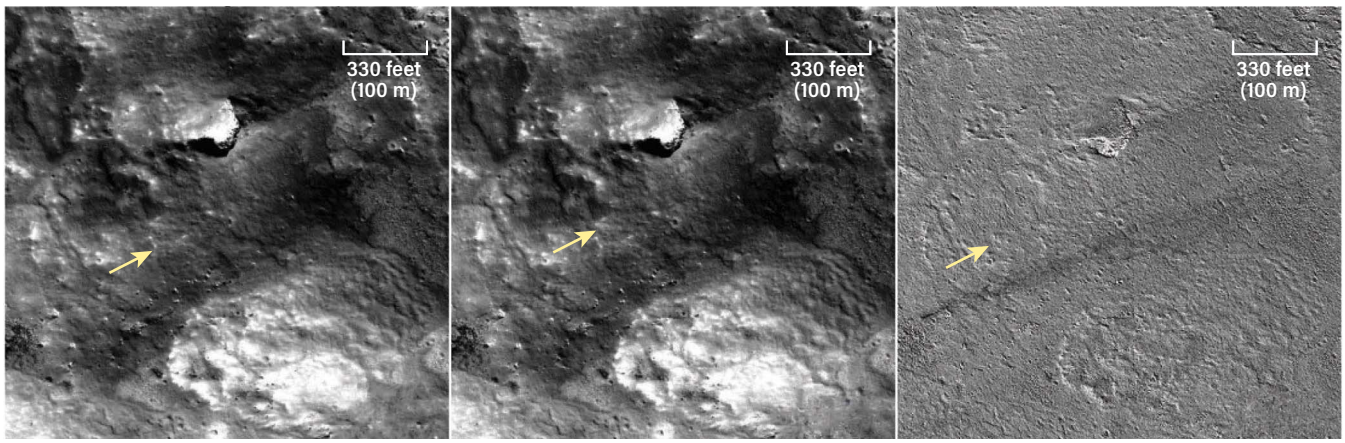
GAS GUZZLER

The supermassive black hole at the center of the Circinus Galaxy, 13 million light-years from Earth, sports two spiral arms that funnel gas to the black hole at speeds of up to 93,000 mph (150,000 km/h), observations from the ALMA radio array indicate.

DARK STARS

A team of researchers has identified four stars in JWST observations with spectra that they say are consistent with the signature of dark stars — theorized supermassive stars in the early universe that are powered by the annihilation of dark matter particles instead of nuclear fusion. – MARK ZASTROW

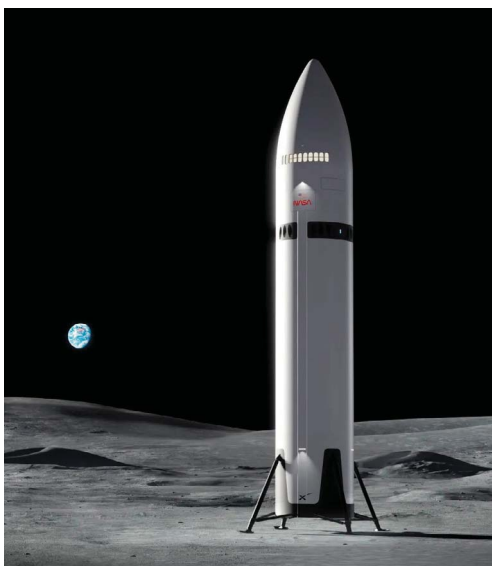
Study shakes up lunar geology



ZHIYONG XIAO ET AL., *NATIONAL SCIENCE REVIEW*/NASA/LROC

THE MOON'S SEISMIC ACTIVITY is evident in these images from NASA's Lunar Reconnaissance Orbiter (LRO), which reveal a before (left) and after (center) view of a newly identified landslide down a 39° slope on the western wall of the Moon's Tycho Crater. The change is highlighted in the image at right, which was created by dividing the after image by the before image. This landslide is one of 41 new events identified from 15 years of LRO images. In 71 percent of the landslides, including this one, researchers could not identify a meteorite strike impact that triggered them. The regions also lacked exposed bedrock, making it unlikely that they were caused by weathering due to repeated expansion and contraction from the vast temperature swings that occur between lunar day and night. This led the team to conclude that internal moonquakes are the primary cause of these recent landslides. The discovery, published Sept. 11 in *National Science Review*, "reminds us the Moon is not a static, dead world," said study leader Zhiyong Xiao of China's Sun Yat-sen University in a press release. It also identifies a potential driver behind an ongoing hazard for future lunar explorers, who must now account for seismic activity when selecting a safe location for a base. —B.M.

NASA REOPENS ARTEMIS 3 LANDER CONTRACT



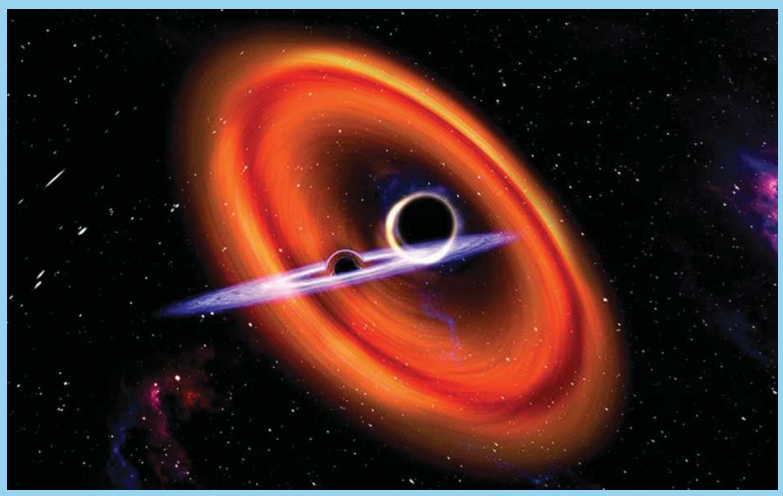
OPEN SEASON. NASA has reopened the contract for the Artemis 3 lunar lander, shown here in an artist's concept. Both SpaceX and Blue Origin are now competing for the mission. SPACEX

NASA is reopening competition for the Artemis 3 human landing system (HLS), the lunar lander slated to return American astronauts to the Moon's surface. Interim NASA Administrator Sean Duffy announced the move Oct. 20, citing concerns that SpaceX's Starship HLS is behind schedule and that NASA is "not going to wait for one company."

Duffy said NASA is in a "race against China," aiming to land on the Moon before the end of President Donald Trump's term in January 2029. NASA's public target for Artemis 3 remains mid-2027, although a 2024 Government Accountability Office report cited an internal confidence rate of 70 percent for February 2028 instead.

SpaceX was originally the sole HLS provider for Artemis 3 and 4. It has been paid about $2.7 billion of its $4.5 billion award for hitting 49 milestones, including demonstrations of HLS life support, thermal control, docking, and landing systems. But it has yet to complete a critical orbital propellant transfer demonstration. That capability, needed to refuel the massive Starship for its trek to lunar orbit, is slated to be tested this year.

In early November, both SpaceX and competitor Blue Origin submitted revised, accelerated landing architectures for the newly opened contract. Blue Origin is already developing its Blue Moon lander for the Artemis 5 mission, but is now a contender for the earlier flight. Blue Origin's plans also rely on the unproven method of refueling at an orbital propellant depot.
—B.M., JACK DALEO



CLOSING IN. When a pair of black holes bound by gravity spirals inward, they create gravitational waves as they lose orbital energy and ultimately merge. Such a pair is imagined in this artist's conception. CARL KNOX, OZGRAV, SWINBURNE UNIVERSITY OF TECHNOLOGY

A PAIR OF UNIQUE BLACK HOLE MERGERS

BY SENSING GRAVITATIONAL WAVES — ripples in space-time — from two distant black hole mergers, the LIGO-Virgo-KAGRA Collaboration has gained insight into how black holes grow by merging. The events — GW241011 and GW241110 — were announced Oct. 28 in *The Astrophysical Journal Letters*.

What made the mergers so unusual was the spins of their black holes. The larger black hole in GW241011, a merger in October 2024 some 700 million light-years away, was one of the fastest-spinning black holes ever seen. Then came GW241110 in November 2024, 2.4 billion light-years away. Its larger black hole was spinning backward — opposite the direction of its mutual orbit with its partner — a "first of its kind" discovery, according to a LIGO press release.

Researchers believe both events are strong evidence that the larger black holes are "second-generation" objects, themselves the products of previous mergers. Astronomers think many so-called intermediate-mass black holes, with masses several hundred times that of the Sun, grow over time as smaller black holes repeatedly merge with one another in dense environments like star clusters, creating ever-larger black holes that capture yet more partners. The chaotic nature of these repeated encounters can result in bizarre, misaligned, or even backward spins.

The lopsided nature of the pairs supports this hypothesis. In both cases, a larger black hole merged with a smaller one, consistent with a massive second-generation black hole capturing a more common, first-generation partner. GW241011 involved two black holes weighing about 20 and six times the mass of our Sun, respectively, while GW241110 comprised black holes 17 and eight times the mass of the Sun.

The accuracy of GW241011's measurement allowed for a precise test of physical theories, such as general relativity and mathematical solutions for the properties of rapidly spinning black holes — both of which matched observations. Furthermore, the rapid spin of GW241011's larger black hole allowed researchers to test theories of hypothetical particles called ultralight bosons, which carry away rotational energy from a black hole, slowing its spin. The fact that the black hole was still spinning rapidly millions of years after forming rules out a wide range of masses for these particles. — B.M.

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STARLINK THREATENS

A sweeping new study reveals unintended satellite emissions are interrupting protected frequencies, just as astronomers prepare to unlock the secrets of the early universe.

SCIENTISTS AT AUSTRALIA'S CURTIN UNIVERSITY in Perth detected more than 112,000 unintended emissions from 1,806 unique SpaceX Starlink satellites over 29 days. These emissions are disrupting observations and jeopardizing the future of radio astronomy.

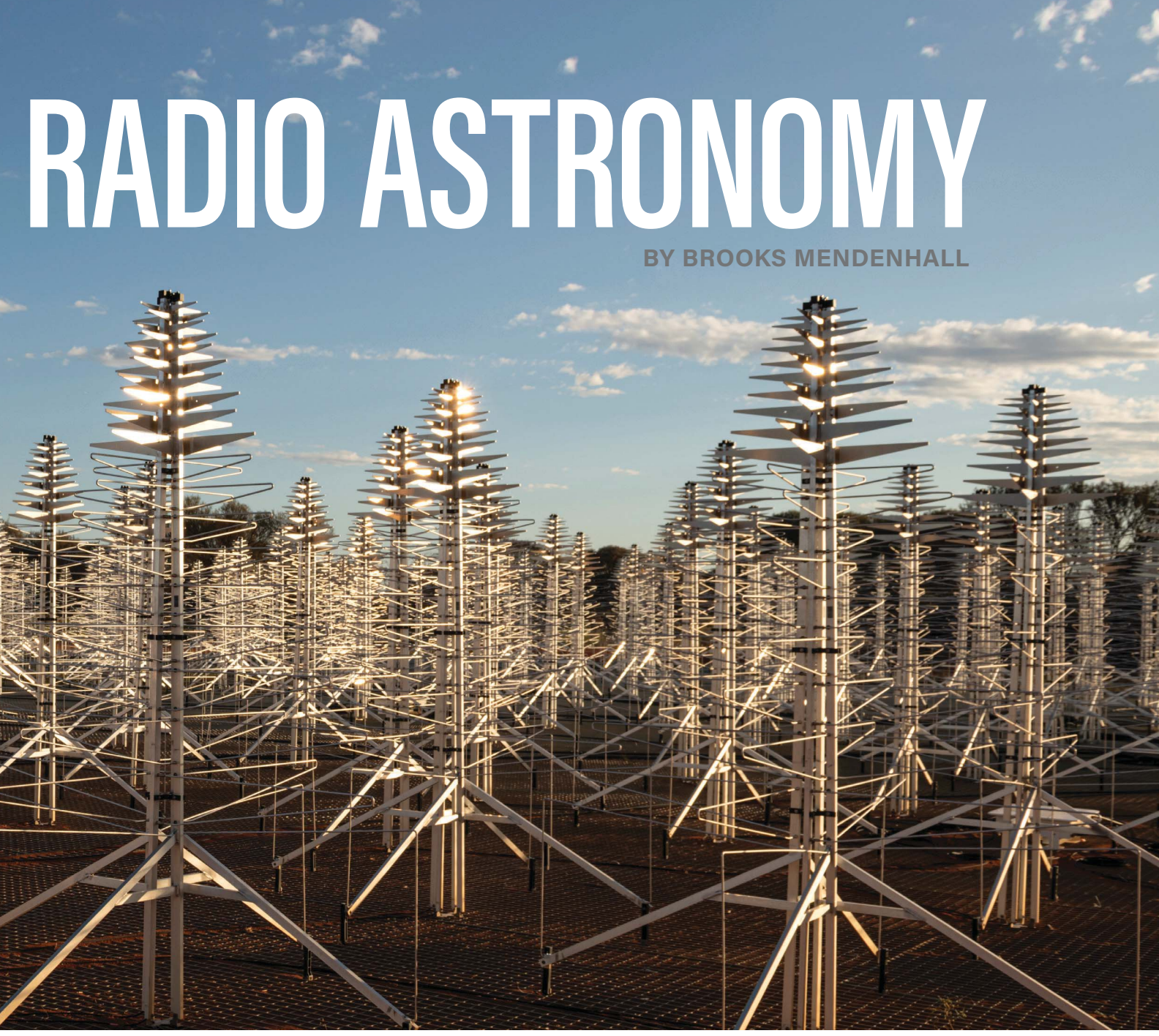
The study, conducted by the Curtin node of the International Centre for Radio Astronomy Research (ICRAR) and published in *Astronomy & Astrophysics*, analyzed 76 million images from a prototype station for the Square Kilometre Array (SKA), soon to be the world's largest and most sensitive radio telescope.

The team detected interference from unintended electromagnetic radiation (UEMR) in up to 30 percent of their images. "Some satellites were detected emitting in bands where no signals are supposed to be present at all," said Dylan Grigg, a Ph.D. candidate at Curtin and lead author of the study.

While the harmful effects of satellite megaconstellations and their light trails on optical astronomy have been well-

RADIO ASTRONOMY

BY BROOKS MENDENHALL



Antennas reminiscent of Christmas trees are arranged at the S8 station of the SKA-Low telescope in Australia. The Curtin University node of ICRAR used a SKA-Low prototype station to analyze 76 million images, detecting Starlink interference in up to 30 percent of them. SKAO/MAX ALEXANDER, CC BY 3.0

documented, their impact on radio astronomy is becoming a growing concern. "Because they may come from components like onboard electronics and they're not part of an intentional signal, astronomers can't easily predict them or filter them out," said Grigg.

A golden era

Starlink is the world's largest satellite internet constellation. It delivers broadband internet from space — including to areas that previously lacked access — but in doing so, it is interfering with radio astronomy.

The challenge lies in ensuring these efforts can coexist. As Christopher De Pree, radio astronomer and National Radio Astronomy Observatory (NRAO) assistant director for spectrum management, notes, "All these human endeavors have value ... someone's ability to check in with their doctor online has value and ... the understanding that there's a black hole at the center of our galaxy has value."

UEMR is radio noise that leaks from electronics. In the case of Starlink, "the specific component of the satellite that causes this unintended emission is unknown," the authors say. A satellite's primary transmitters — which, for Starlink, includes those that transmit internet signals to users — operate on predictable, licensed frequencies, but UEMR is erratic, making it harder for astronomers to deal with.

It is particularly disruptive to low frequencies (typically below 1 GHz), which are used to study the cosmic dawn. Having traveled billions of light-years,

SpaceX regularly launches batches of its Starlink satellites, like the mission seen here. At the time of the study, the constellation had over 7,000 satellites in orbit and continues to grow rapidly. SPACEX

these cosmic dawn signals are faint and easily overwhelmed. As Greg Hellbourg, spectrum manager at Caltech explains, low-frequency instruments have wide fields of view to capture these faint signals. However, he says, they also "capture UEMR 'for free'" as satellites drift by.

According to Steven Tingay, the executive director of the Curtin Institute of Radio Astronomy and study co-author, the timing of this threat is especially critical. "We're standing on the edge of a golden era where the SKA will help answer the biggest questions in science: how the first stars formed, what dark matter is, and even test Einstein's theories," Tingay stated.

UEMR could very well make those answers harder to find. Tingay says some of the science will be manageable, but "where the science demands the most sensitive observations and contamination-free data, I personally think that the impacts may be significant."

The growing impact on astronomy

Radio interference (RFI) is not a new problem, but the scale and intensity are worsening. As far back as the 1980s, signals from the Soviet-era Global Navigation Satellite System bled into radio frequencies reserved for science.

Starlink's sheer size, however, has changed the game. The constellation had over 7,000 satellites in orbit at the time of the study, with 477 launched during the observation period alone and more on the way. As Starlink grows, so does the UEMR problem. A 2024 study using the Low-Frequency Array telescope in the Netherlands found that second-generation Starlink satellites produce UEMR 32 times stronger than their predecessors. Hellbourg adds UEMR is not unique to Starlink, with "evidence from multiple low Earth orbit constellations" now emerging.

A gap in the rules

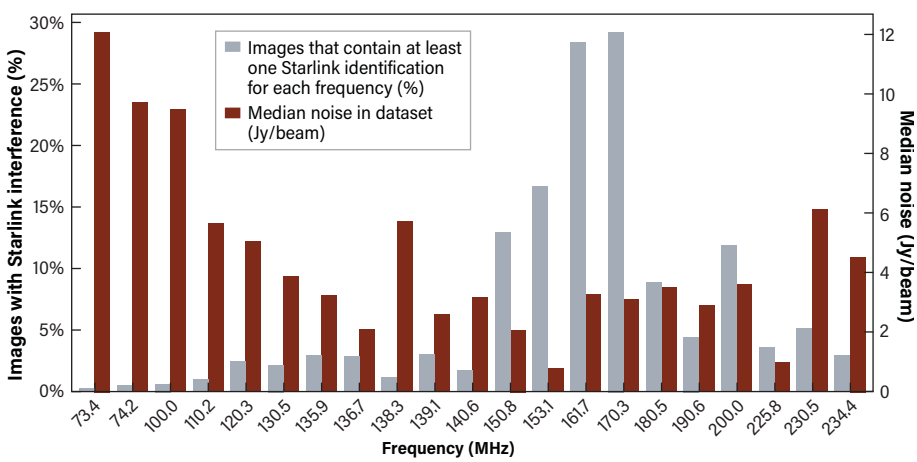
According to Tingay, Starlink is not violating any rules. Technically, SpaceX is "doing nothing wrong," he explained. The problem lies with the regulations themselves, which have not kept pace with modern satellite technology.

The International Telecommunication Union (ITU), a United Nations agency, created protected frequency bands decades ago, but its rules focus on intentional transmissions. As Tingay explained, they "do not cover this type of unintended emission." This regulatory gap means there is little policy framework guiding satellite design or holding operators accountable for UEMR. Hellbourg clarifies the gap is nuanced: while a key regulation "prohibits any emission whatsoever" in protected bands,

VISUALIZING THE PROBLEM

Data from the Curtin study shows the percentage of the SKA-Low images contaminated by Starlink interference at key frequencies, as visualized in this graph. The rate peaked at nearly 30 percent in some datasets; interference was lower at noisy frequencies, likely because the noise obscured the satellite signals.

ASTRONOMY: ROEN KELLY, AFTER D. GRIGG ET AL., 2025, DOI: 10.1051/0004-6361/202554787



A Starlink payload is seen here stacked shortly before orbital deployment. With more than 7,000 satellites in orbit during the study, their sheer number is contributing to the growing problem of radio interference. SPACEX

it "does not specify thresholds," leaving a gray area for enforcing how much UEMR is too much. This is a problem that will worsen, as aggregate UEMR from tens of thousands of future satellites threatens to raise the entire noise floor.

Attempts at cooperation

Regarding interference from optical brightness that intrudes on images produced by astronomers, SpaceX has been publicly responsive, developing engineering solutions like visors and dielectric mirrors — film that scatters light away from Earth.

SpaceX has also been quick to address issues with intentional RFI. In 2019, the company signed an agreement with the U.S. National Science Foundation (NSF), committing to protecting radio astronomy frequency bands through methods like sharing satellite location data with observatories and steering transmission beams away from sensitive sites.

Collaboration has been furthered by the NRAO's Operational Data Sharing (ODS) system.

"[ODS] allows our radio telescopes to share in near-real time where our telescopes are pointed in the sky," explains De Pree. "This information is utilized by SpaceX to make sure that satellites passing close to our pointing position do not transmit at our observing frequency."

Originally only active at the Very Large Array in New Mexico, ODS was recently implemented in September 2025 at the Very Long Baseline Array — a system of 10 radio telescopes scattered across the U.S. The NRAO hopes to add ODS for the Green Bank Telescope in West Virginia as well.

While these mitigation efforts from SpaceX are promising, UEMR is a separate, more difficult challenge. "UEMR is certainly a different issue than signals associated with intended emissions, and also poses greater challenges to radio telescopes that operate more frequently at low frequencies," De Pree says, noting that these signals can be intermittent and hard to trace.

> "WE'RE STANDING ON THE EDGE OF A GOLDEN ERA WHERE THE SKA WILL HELP ANSWER THE BIGGEST QUESTIONS IN SCIENCE."

The authors of the paper say that a private dialogue with SpaceX is underway, with Tingay noting that "discussions we have had with SpaceX on the topic have been constructive."

According to De Pree, SpaceX was an active participant in recent discussions at September 2025 ITU meetings in Geneva. "My perception is … Starlink and SpaceX are very much acting in good faith about UEMR and being very open," De Pree says. SpaceX did not respond to *Astronomy*'s requests for comment on the issue.

Searching for solutions

Astronomers are proposing both technical and regulatory solutions to the UEMR problem with a heavy emphasis on collaboration and communication.

"Careful RFI testing of satellite systems before launch, and the sharing of these tests with radio observatories to give feedback about the detected UEMR, would be a good first step," De Pree suggests. "These types of issues are much easier to identify and solve before the launch."

This collaborative testing could be facilitated by the National Radio Dynamic Zone (NRDZ), an idea proposed by De Pree in 2023. The NRDZ would serve as a testbed where astronomers and satellite companies codevelop technologies on the ground that are "mutually aware" and designed not to interfere with each other. While similar

The NRAO's Very Large Array (VLA) uses an Operational Data Sharing (ODS) system to tell Starlink where its telescopes are pointing, allowing SpaceX to steer intentional transmissions away from the sensitive site — an example of ongoing collaboration. MIHAISISCANU, CC BY 4.0

to ODS in its emphasis on cooperation and communication, the NRDZ would resolve issues before launch. However, progress on a dedicated facility has slowed due to "uncertainty at the federal level," according to De Pree, and is likely "a ways off in the future."

Satellite operators often can't detect UEMR themselves, as they "don't run instruments at radio telescope sensitivities," says Hellbourg. He leads an International Astronomical Union Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference working group that monitors emissions. In a collaborative approach similar to De Pree's NRDZ, the group shares results with satellite operators "so they can pinpoint specific hardware contributors" for future builds.

Like De Pree and Hellbourg, Tingay believes working with operators is key but also wants to raise public awareness, warning that this level of interference can have far-reaching impacts for everyone. Disrupting our view of the universe "impacts our ability to make fundamental new discoveries" and "turn those discoveries into technologies and inventions" for future generations, he says.

Tingay says that astronomers should also invest in algorithms that filter out interference. He notes that while UEMR's high variability makes filtering "very difficult," his team is seeing "pretty promising" early results by pairing real observational data with a Swiss team's software, moving their work from simulation to reality. He cautions, however, that "there is a very long way to go."

Future collaborations

Ultimately, a lasting solution requires policy change. If the ITU updates its guidelines to cover UEMR, future policy could mandate shielding requirements (enclosures around electronics that prevent radiation), UEMR thresholds, or standardized testing before launch.

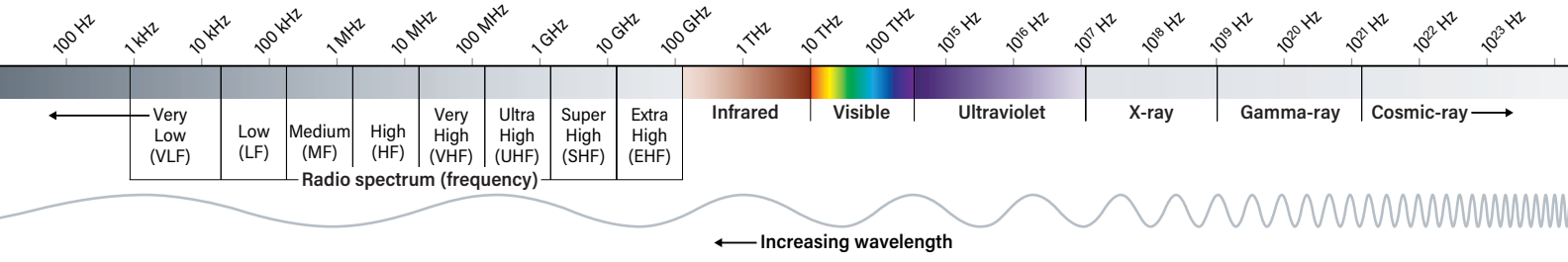
The authors of the Curtin study frame the road ahead as one of collaboration: "Future mitigation of the UEMR from Starlink satellites will be key for ultra-sensitive experiments with SKA. … SpaceX has made significant progress liaising with astronomers in the optical domain, and we hope to keep this dialogue open in the radio domain."

De Pree remains hopeful. "I'm a technological optimist," he says. He envisions a future where astronomers and companies "work together to develop components that are mutually aware. That could be a really great solution in the decades ahead."

Brooks Mendenhall *is a staff writer for* Astronomy, *and is based in Chattanooga, Tennessee.*

ACROSS THE SPECTRUM

The electromagnetic spectrum encompasses radio waves, which astronomers utilize to study phenomena invisible to the naked eye in optical light. Unintended emissions from satellites are increasingly leaking into protected radio bands, particularly affecting sensitive low-frequency observations below 1 GHz. NASA



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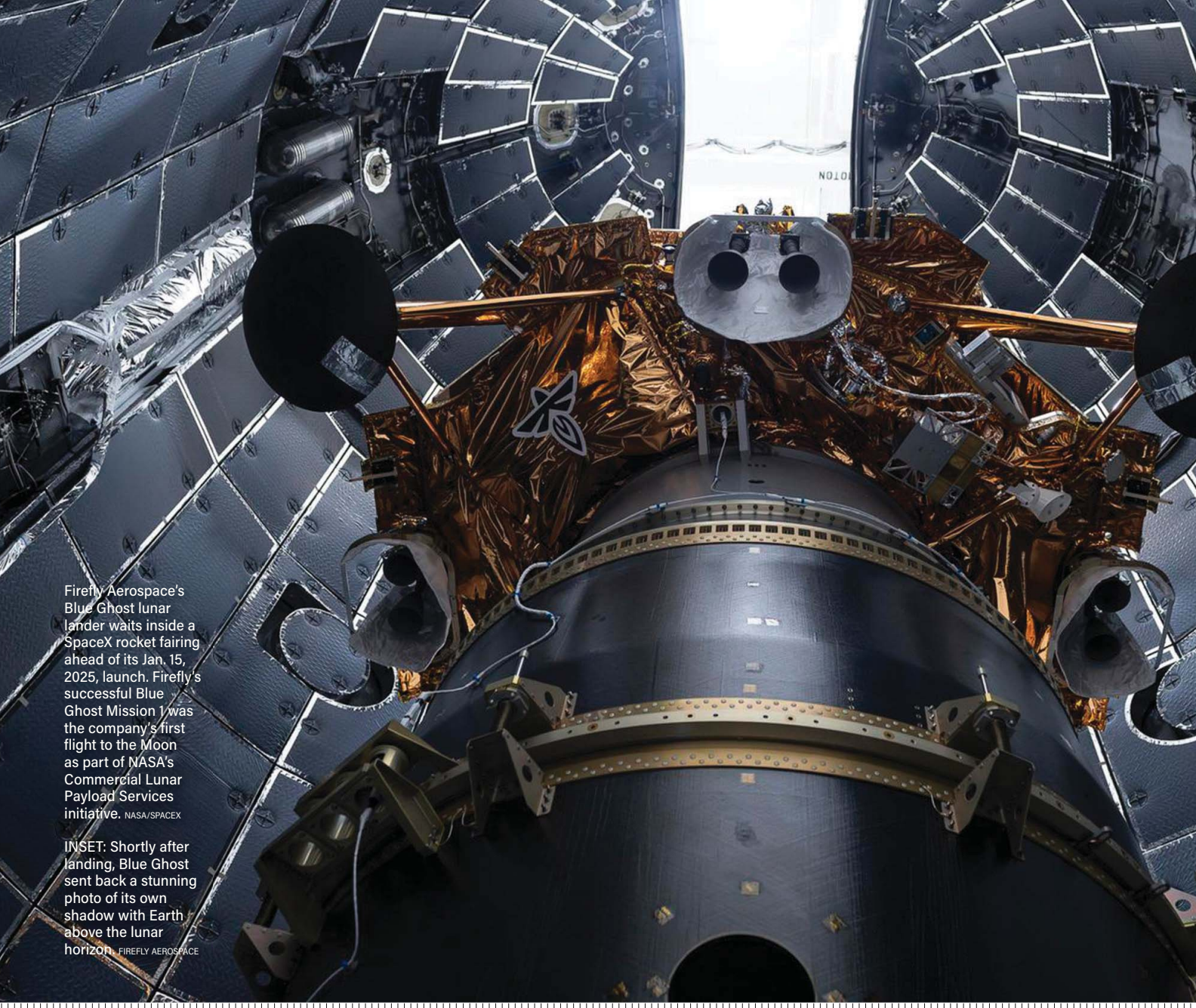


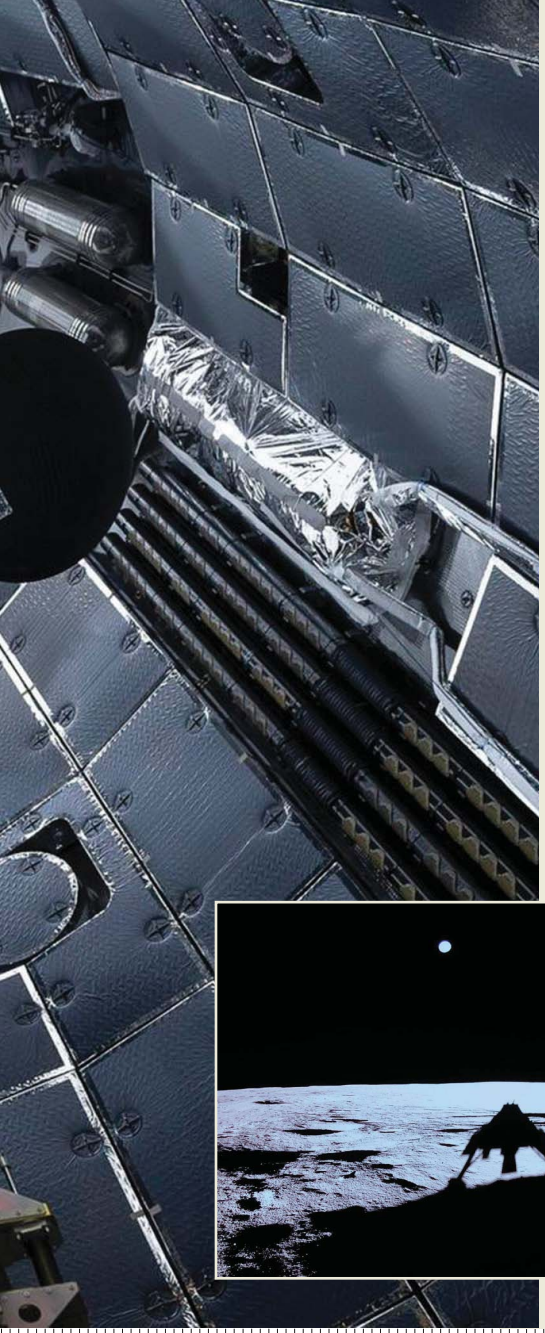
Firefly Aerospace's Blue Ghost lunar lander waits inside a SpaceX rocket fairing ahead of its Jan. 15, 2025, launch. Firefly's successful Blue Ghost Mission 1 was the company's first flight to the Moon as part of NASA's Commercial Lunar Payload Services initiative. NASA/SPACEX

INSET: Shortly after landing, Blue Ghost sent back a stunning photo of its own shadow with Earth above the lunar horizon. FIREFLY AEROSPACE

TOP 10 SPACE ST

Amid federal funding uncertainty, commercial spaceflight saw highs and lows, a comet from another star surprised us, and the Vera C. Rubin Observatory began its 10-year survey. **BY ALISON KLESMAN, BROOKS MENDENHALL, AND MARK ZASTROW**

OUR PICTURE OF THE COSMOS is ever-changing, transformed by new discoveries. In 2025, we learned evidence is now piling up to suggest that the mysterious dark energy that guides the evolution of our universe may not be constant over cosmic history, but might grow weaker over time. A new interstellar visitor swung past the Sun,



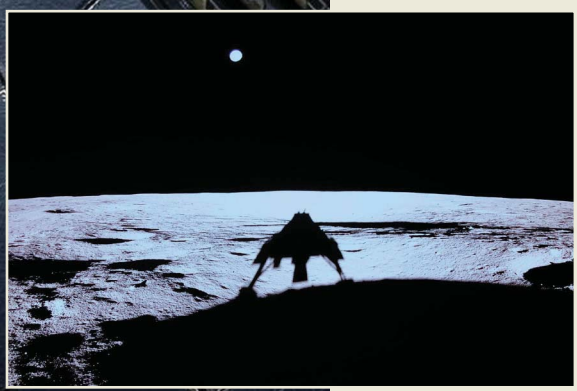
Blue Ghost succeeds amid private Moon mission struggles

10

Last year in these pages, we referred to 2024 as the new golden age of lunar exploration. That golden age continued in 2025, though not without drama. While communication with NASA's Lunar Trailblazer orbiter mission was lost shortly after its February launch and ispace's Hakuto-R Mission 2 crashed in June, Firefly Aerospace's Blue Ghost Mission 1 delivered a historic success. The mission launched on a SpaceX Falcon 9 alongside Hakuto-R. But while Hakuto-R crashed during landing, Blue Ghost's flawless touchdown made it the most successful private lunar mission to date.

Nicknamed "Ghost Riders in the Sky," the mission launched Jan. 15, 2025, and began a-plowing through the ragged skies on a rambling path that included 25 days orbiting Earth, a four-day lunar transit, and 16 days in lunar orbit. This allowed for robust health checks before the final descent. It paid off: On March 2, the lander executed a picture-perfect autonomous landing near Mons Latreille on the eastern edge of Mare Crisium — a large, dark volcanic plain on the Moon's nearside. Operating there for over 14 Earth days, Blue Ghost sent home a trove of data totaling more than 119 GB.

All 10 NASA instruments in its payload performed as expected and achieved key goals. The Lunar GNSS Receiver Experiment showed GPS and Galileo signals could be used for lunar navigation, and the Next Generation Lunar Retroreflector bounced laser pulses back to Earth, providing submillimeter measurements of the distance from Earth to the Moon. Blue Ghost also captured high-definition imagery of a total solar eclipse from the lunar surface — where Earth blotted out the Sun — a first for a commercial company.



The mission also flawlessly performed experiments that touched and sampled the surface. The Lunar PlanetVac successfully collected lunar soil, while the Lunar Instrumentation for Subsurface Thermal Exploration with Rapidity drilled about 3 feet (1 meter) into the surface to measure heat flow. The Electrodynamic Dust Shield and Regolith Adherence Characterization experiments also provided valuable data on lunar dust.

Blue Ghost's triumph served as an ideal demonstration of NASA's Commercial Lunar Payload Services program, showing how the program can act as a crucial steppingstone for the future of commercial exploration and help pave the way for a lasting human presence on the Moon.

TORIES OF 2025

while observations from our own solar system and beyond continued to shape the way we look for life.

The year wasn't without its challenges, as the submission of several competing budgets for NASA science included a proposed massive reduction in the number of current and future missions. And despite the lauded success of Firefly Aerospace's Blue Ghost 1, the first commercial landing on the Moon, other companies failed to re-create the triumph. Nonetheless, our satellite remains a tempting target and valuable science goal for future endeavors, and will be a prime destination throughout 2026.

And as astronomers build on past successes and follow new avenues for discovery, the field is poised for change as the Vera C. Rubin Observatory begins its 10-year Legacy Survey of Space and Time. We are now preparing to ask questions about the cosmos we haven't even thought of yet.

FINDS CLOSE TO HOME

Close is always a relative term in astronomy, but some of the nearest and most familiar objects in our night sky were found in 2025 to have previously hidden companions.

A possible Neptune-like exoplanet was found around the nearby star **Alpha (α) Centauri A**, which is also known as Rigil Kentaurus and is the most massive star in Alpha Centauri, the star system closest to the Sun. The candidate world was imaged by NASA's JWST in observations published in August.

Three exoplanets were discovered around **Barnard's Star** — which, at 6 light-years away, is the closest single star (not in a multiple system) to the Sun. Identified in ground-based radial velocity data and reported in March, this trio of planets joins the star's first exoplanet, which was confirmed in 2024.

Betelgeuse — the famously ruddy red giant on the shoulder of Orion — was confirmed to have a companion via a direct image taken by the Gemini North Telescope located atop Maunakea in Hawaii. This work, published in July, followed up on strong suspicions of a second star, raised in 2024 in separate indirect analyses of variations in Betelgeuse's brightness, position, and radial velocity.

And in March, in a surprising find, researchers reported that the **Large Magellanic Cloud** (LMC) — one of the Milky Way's closest neighbors — may have a supermassive black hole at its center. The evidence is thanks to ESA's Gaia mission, which observed a collection of 21 stars on the outskirts of the Milky Way traveling so fast they will escape the galaxy. Their trajectories trace back to the LMC, where the team thinks they were ejected after a close encounter with the black hole.

Starship Test Flight 10 launched from Starbase, Texas, on Aug. 26, 2025, completing all its major mission objectives. SPACEX

An interstellar comet comes to visit

On July 1, the Asteroid Terrestrial-impact Last Alert System (ATLAS) reported a new find some 418 million miles (673 million kilometers) from the Sun, inside the orbit of Jupiter. Calculations showed that although the object was moving through the solar system, it was not from the solar system. Called 3I/ATLAS, it became the third known interstellar object (ISO); within 24 hours, signs of cometary activity earned it the additional designation C/2025 N1 (ATLAS).

Moving at 130,490 mph (210,000 km/h) — faster than the two previously discovered ISOs, 1I/'Oumuamua and 2I/Borisov — 3I/ATLAS' path brought it close to Mars Oct. 3, passing some 18.6 million miles (30 million km) from the Red Planet, where several robotic spacecraft observed it. 3I/ATLAS then made its closest approach to the Sun Oct. 29 (126 million miles [202.9 million km]), still outside the orbit of Earth. Then it went streaking toward the outer solar system again, never to return. On the way, it passed Earth Dec. 19 at a distance of 167.8 million miles (270 million km), posing no threat to our planet.

As only the third known interstellar visitor, 3I/ATLAS is adding valuable details to our still-murky picture of these objects. Each new example has taught us about conditions elsewhere in the galaxy, particularly how planets, asteroids, and comets form around other stars.

The comet's size was difficult to pin down, with early estimates suggesting it could be as large as 6 to 12 miles (10 to 20 km). By late August, astronomers had downsized its breadth, based in part on observations by Hubble and the James Webb Space Telescope (JWST), to between 0.3 and 3.5 miles (0.44 to 5.6 km) across. The revised upper limit — 3.5 times the size of Comet Borisov — still suggests there may be more large ISOs than previously thought.

Based on its speed and direction of origin in Sagittarius, the direction of the galaxy's center where older stars reside, a paper published Sept. 1 in *The Astrophysical Journal Letters* suggests the comet could be some 7.6 billion years old, predating our solar system, and contain a high fraction of water, based on the environment where it likely formed. Speaking at the Royal Astronomical Society's July meeting in Durham, U.K., study

Starship's busy year of test flights

In the biggest year yet for private spaceflight, SpaceX led the charge. As of September, the company had conducted more than 120 orbital launches with its Falcon 9 rocket and was aiming for a total of 170 by year's end. But none of those commanded as much attention as test flights of the company's Starship — whose success is integral for America's return to the Moon.

Starship, which comprises the Super Heavy booster and the Starship upper stage, is designed for full, rapid reusability. It is the most powerful launch vehicle ever built. While NASA's Space Launch System (SLS) will launch the crewed Orion capsule to lunar orbit, the Super Heavy booster will send a Starship Human Landing System (HLS) spacecraft to Earth orbit. The booster will also launch the multiple Starship tanker spacecraft needed to refuel HLS before its journey to the Moon.

The year began with a series of critical failures. January's Test Flight 7 suffered a propellant leak, which caused the upper stage vehicle to break apart over the Caribbean. Test Flights 8 and 9, in March and May, respectively, failed to achieve their primary objectives due to issues with the vehicle's heat shield and landing system. These setbacks provided invaluable data, however, for SpaceX's signature rapid-iteration approach. Elon Musk, the company's CEO and founder, has famously remarked, "Failure is an option here. If you're not failing, you're not taking enough risks."

A breakthrough came with August's Test Flight 10, which achieved a flawless ascent and reached a stable orbit for the first time. It then deployed a payload mass simulator, demonstrating its capability to deliver cargo. On the way back, the ship executed a perfect belly-flop descent and soft landing.

This was followed by the 11th test flight Oct. 13. While the Super Heavy booster tested a unique, hovering landing burn before its splashdown in the Gulf of Mexico, the Starship upper stage successfully deployed eight Starlink simulators, performed the third in-space relight of a Raptor engine, and gathered critical data during a stress test of its heat shield upon reentry before its own soft splashdown in the Indian Ocean.

This concluded the test campaign for the Version 2 vehicle and cleared the path for the upgraded Version 3, expected in early 2026. A number of milestones remain before the vehicle is ready for crewed missions, including in-space refueling demonstrations and further testing of critical life-support systems.

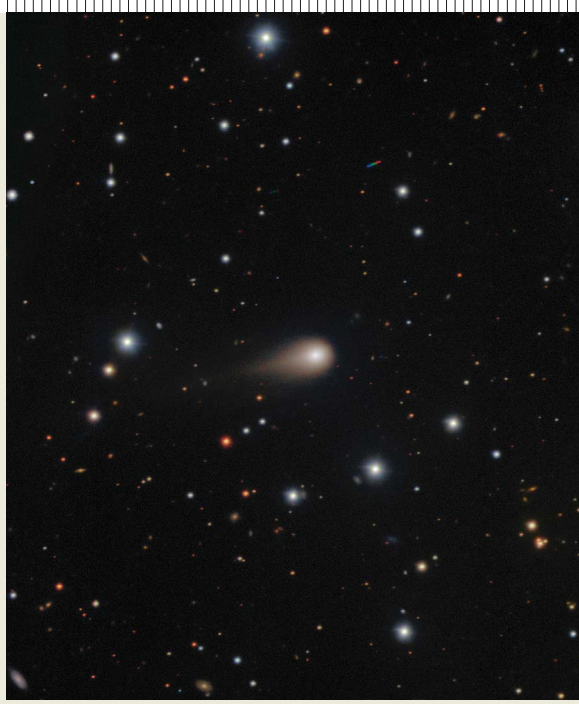
The year was punctuated by other developments in private space exploration. Blue Origin launched its New Glenn rocket for the first time, while United Launch Alliance's USSF-106 mission showcased its continued reliability. Rocket Lab's Neutron rocket also made critical strides, hinting at a future where access to space is more routine and affordable than ever before.

first author and University of Oxford researcher Matthew Hopkins called 3I/ATLAS "very likely to be the oldest comet we have ever seen."

As the comet approached the Sun, astronomers looked for chemical fingerprints as ices on the surface sublimated, creating a coma of gas and dust, and a lengthening, teardrop-shaped tail. A study posted Sept. 30 to the *arXiv* preprint server and submitted to *Astronomy & Astrophysics* noted an "extremely puzzling" abundance of iron and nickel in the coma compared to either solar system comets or Comet Borisov. "[C]omet 3I is either metal-rich … or, more likely, it has enhanced metal production due to chemical anomalies," it states. Those anomalies include observations that appeared in a different study published Sept. 26 in *The Astrophysical Journal Letters*, in which JWST data indicate 3I/ATLAS is particularly rich in carbon dioxide. The authors write this "may indicate that 3I/ATLAS contains ices exposed to higher levels of radiation than solar system comets," or that it coalesced in the region around its parent star where temperatures were cold enough for carbon dioxide to form ice.

And a Sept. 30 paper in *The Astrophysical Journal Letters* reported signs of water spewing from the comet as hydroxyl (OH), a byproduct of water production, was spotted while 3I/ATLAS was still three times the distance of Earth from the Sun. This is too far for sunlight to turn water ice on a comet's surface into gas, so researchers theorized the comet was releasing a stream of tiny, ice-covered dust particles, which were more easily heated by the Sun.

Like all other interstellar visitors, 3I/ATLAS will never return, taking its secrets with it. But with the commencement of the Vera C. Rubin Observatory's Legacy Survey of Space and Time, astronomers expect to identify some five to 50 new ISOs in the next decade, soon increasing dramatically the pool of galactic wanderers available to teach us about other star systems.

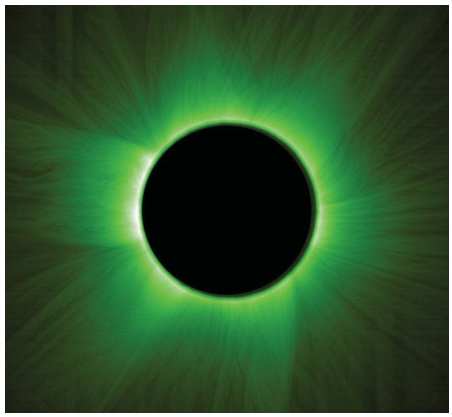


The 8.1-meter Gemini South telescope in Chile captured this image of Comet 3I/ATLAS on Aug. 27. The composite, which combines a deep stationary background shot with images that tracked the faster-moving comet, shows 3I/ATLAS' coma as well as its growing tail. The small, tri-colored trails were left by asteroids moving across the field. INTERNATIONAL GEMINI OBSERVATORY/NOIRLAB/NSF/AURA/SHADOW THE SCIENTIST. IMAGE PROCESSING: J. MILLER & M. RODRIGUEZ (INTERNATIONAL GEMINI OBSERVATORY/NSF NOIRLAB), T.A. RECTOR (UNIVERSITY OF ALASKA ANCHORAGE/NSF NOIRLAB), M. ZAMANI (NSF NOIRLAB)

7 Solar Orbiter, PUNCH, and Proba-3 show us the Sun

With a convergence of major missions delivering groundbreaking new insights into the Sun and its dynamic environment, 2025 was a landmark year for heliophysics. Rather than a single event, the field celebrated a series of wins that transformed our understanding of our closest star. At the forefront of this new era were the Polarimeter to Unify the Corona and Heliosphere (PUNCH), Solar Orbiter, and Proba-3 missions, each providing a unique perspective on the Sun.

The NASA PUNCH mission launched in March and quickly began its work. Its first stunning images of coronal mass ejections (CMEs) were unveiled in June at the 246th American Astronomical Society meeting, and showed the CMEs blasting out from the Sun and traveling across the inner solar system. Composed of four small satellites flying in precise formation, PUNCH's cameras work together as a single "virtual instrument" to capture a continuous, three-dimensional view of how the solar wind of charged particles flows from the Sun's outer corona. By stitching together images from its Wide Field and Narrow Field Imagers, the mission creates videos with unprecedented detail of CMEs evolving, marking a big step in improving space weather forecasting.



The solar corona was imaged by Proba-3's ASPIICS coronagraph. ESA/PROBA-3/ASPIICS/WOW ALGORITHM, CC BY-SA 3.0 IGO

The European Space Agency's (ESA) Solar Orbiter mission delivered a world first in 2025, providing humankind's first direct images of the Sun's south pole. From Earth, a clear view of the Sun's poles is impossible because the planets and most spacecraft orbit within a flat plane. To work around this, Solar Orbiter used a series of gravity assists from Venus to tilt its orbit, eventually climbing to a 17° angle out of this plane and getting a unique perspective on the Sun's polar regions. The images, captured by its Polarimetric and Helioseismic Imager and Extreme Ultraviolet Imager instruments, revealed a chaotic, messy magnetic field at the pole. This is a key sign that the Sun's magnetic field is undergoing its periodic pole flip at the peak of the solar cycle, as both positive and negative magnetic fields were present. These never-before-seen images will help researchers understand how the Sun's global magnetic field operates.

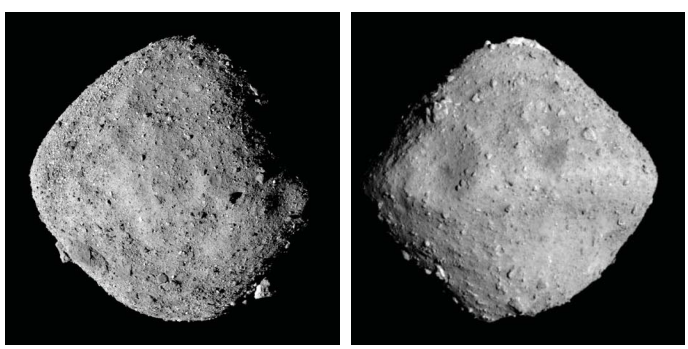
Finally, ESA's Proba-3 mission successfully executed an audacious technological feat, creating the world's first sustained artificial solar eclipse. By flying two Earth-orbiting satellites in precise formation 490 feet (150 m) apart, the mission's lead satellite was able to perfectly block the Sun's blinding disk for the secondary craft, allowing the latter to image the faint inner corona. This innovative approach provides an unprecedented and continuous viewing platform for a region previously only observable during fleeting natural eclipses, offering invaluable data on the Sun's atmosphere and helping to improve space-weather predictions.

6 Bennu and Ryugu may be siblings

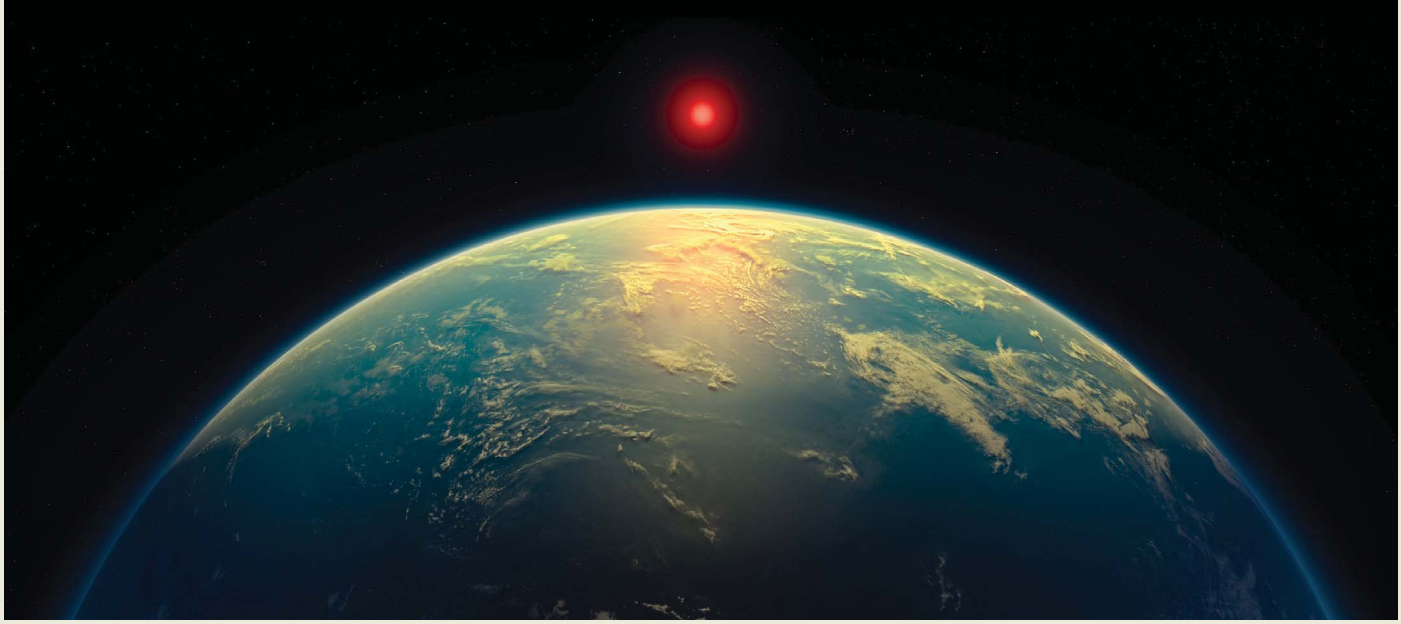
101955 Bennu and 162173 Ryugu share many similarities. Both are near-Earth asteroids that orbit between Earth and Mars. But neither formed there — they were forged farther out in the solar system and later pushed into their current orbits, likely by Jupiter's gravity. Both are carbon-rich "rubble pile" asteroids assembled from pieces of a parent body after a collision. They are even similarly shaped, though 0.6-mile-wide (0.9 km) Ryugu is twice Bennu's size. And both are in an elite club of asteroids whose material has been returned to Earth: Japan's Hayabusa2 dropped off samples of Ryugu in December 2020 and NASA's OSIRIS-REx delivered pieces of Bennu in September 2023.

Yet another similarity came to light Aug. 18 in a paper in *The Planetary Science Journal*: Astronomers think Ryugu and Bennu may have come from the same parent body, the largest piece of which is 34-mile-wide (55 km) main-belt asteroid 142 Polana.

The study, led by postdoctoral researcher Anicia Arredondo at the Southwest Research Institute (SwRI) in San Antonio, Texas, picked apart the light each asteroid reflects in the infrared portion of the spectrum. The team compared data from Bennu and Ryugu samples in the lab as well as those taken by the spacecraft that visited them with new JWST observations of both asteroids and Polana. Ultimately, "they are similar enough that we feel confident that all three asteroids could have come from the same parent body," Arredondo said in a press release.



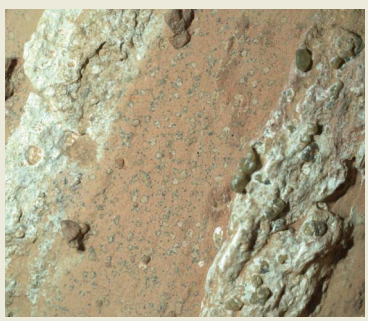
Asteroids Bennu (left) and Ryugu have much in common: their shape, structure, and the fact they have both been visited by spacecraft. Now, researchers believe both are the product of a single collision, which also left behind the main-belt asteroid Polana. FROM LEFT: NASA/GODDARD/UNIVERSITY OF ARIZONA; JAXA, UNIVERSITY OF TOKYO, KOCHI UNIVERSITY, RIKKYO UNIVERSITY, NAGOYA UNIVERSITY, CHIBA INSTITUTE OF TECHNOLOGY, MEIJI UNIVERSITY, UNIVERSITY OF AIZU, AIST



Biosignatures buzz

Are we — and have we always been — alone in the universe? Two studies in 2025 raised these age-old questions, with one drawing significant controversy along the way.

On April 16, U.S. and U.K. news outlets heralded findings led by astronomer Nikku Madhusudhan of the University of Cambridge. Using data from JWST of K2-18 b — a planet roughly half Neptune's mass — his team had "detected the most promising signs yet of a possible biosignature outside the solar system," said a press release. The team claimed a highly suggestive — but not definitive — detection of dimethyl sulfide (DMS), a molecule that on Earth is only known to be produced by life. Based on the planet's other spectral features, the team suspected it is a water world, potentially with a marine ecosystem. "Currently, there is no way to explain DMS at the levels we are seeing without life," said Madhusudhan in an April 17 public lecture.



ABOVE: One team of researchers thinks that K2-18 b is what they call a hycean world — one with a global water ocean and a hydrogen-rich atmosphere, as shown in this artist's concept. A. SMITH, N. MADHUSUDHAN (UNIVERSITY OF CAMBRIDGE)

LEFT: The "leopard spots" found by Perseverance in the rock called Cheyava Falls told researchers that unusual chemistry had taken place there. NASA/JPL-CALTECH/MSSS

But when independent researchers reanalyzed the data, published April 17 in *The Astrophysical Journal*, some found no evidence of DMS. Others were critical of the methods, citing an unrealistically simplified baseline model atmosphere.

Madhusudhan said that regardless of whether the team had actually found life on K2-18 b, it was significant that "we are demonstrating the capability to do that" with JWST. But others, like astrobiologist Keven Zahnle of NASA's Ames Research Center, thought JWST was starting to show its limits. "It wasn't built to detect life on other planets," Zahnle told *Astronomy*. "It does as well as it can — it does better than anything else we have ever built — but it was built to do other things."

Attention shifted closer to home Sept. 10 when NASA announced that analysis of a sample collected by its Perseverance rover on Mars had yielded a potential biosignature — possible fossilized evidence of ancient microbial life. The rock, discovered by the rover in July 2024 and named Cheyava Falls, has a peculiar spotted pattern. Analysis revealed spectral signs of organic matter and minerals that could have been excreted by ancient microbes. NASA's acting administrator, Sean Duffy, called it "the closest we have ever come to discovering life on Mars."

Researchers say the only way to rule out nonbiological origins for the minerals is to analyze the samples in more powerful labs back on Earth. NASA has spent the last year and a half retooling its plans to do so; it says it will announce a new Mars sample-return mission concept in the second half of 2026.

They are not a perfect match. Bennu and Polana are B-type asteroids; Ryugu is classified as a Cb-type asteroid. Both categories fall under the same family of carbon-rich bodies, with slight differences in their underlying composition. There are also differences between Polana and Bennu's spectra. However, the team believes these differences can be explained by the asteroids' varying histories. "Polana, Bennu, and Ryugu have all had their own journeys through our solar system since the impact that may have formed them," said study co-author Tracy Becker, also of SwRI. Differences in the amount of space weathering each has undergone — bombardment over time by micrometeoroids as well as solar photons — as well as variations in the size of their surface grains and the way each asteroid assembled from the collision's debris could all create their subtle differences today.

The team now hopes to use the results to better understand how an asteroid's unique history affects its spectrum, which in turn will improve our picture of the solar system's formation and evolution with time.

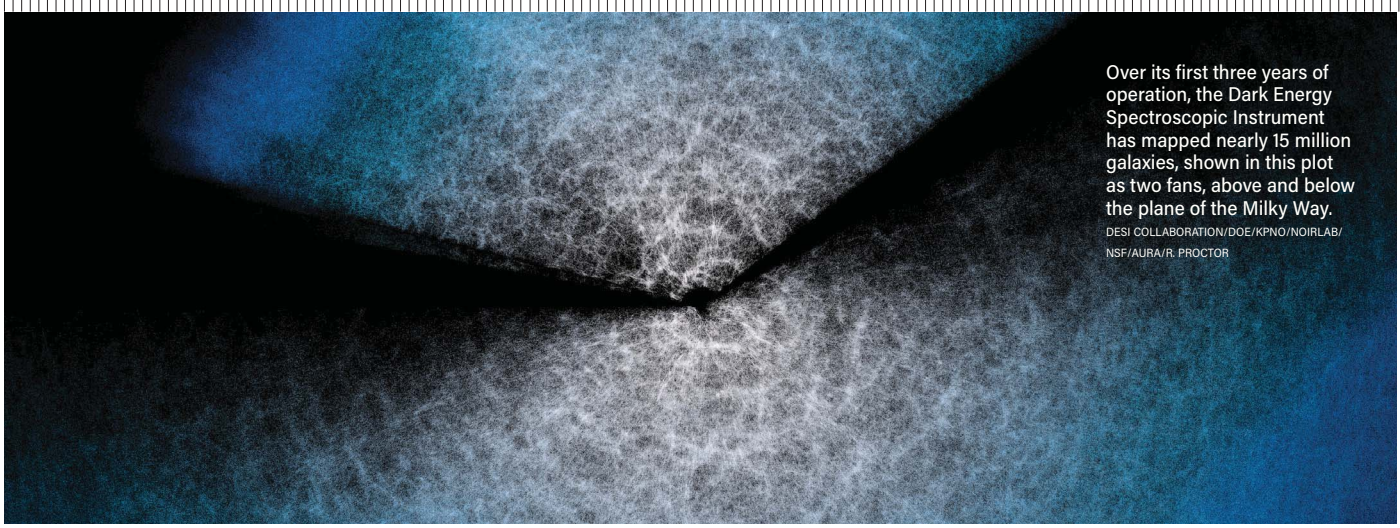
4 Early galaxy spotted clearing cosmic fog

Beginning around 380,000 years after the Big Bang, our universe was plunged into darkness. At this time, it was filled with neutral hydrogen gas, which absorbs light and created a "fog" that pervaded the universe, making it impossible for light to travel great distances. This time was called the Dark Ages. But as stars and then galaxies formed, they sent out high-energy ultraviolet (UV) photons that ionized the hydrogen, knocking the atoms' electrons away. Ionized hydrogen is transparent to light; over time these early stars and galaxies cleared the cosmos so that today we can see across vast distances and back to early times. This era was the Epoch of Reionization, and it ended about a billion years after the Big Bang.

Astronomers don't yet have a clear picture of this process from start to finish. But that's changing thanks to discoveries made by JWST, including one reported March 26 in *Nature*, outlining a galaxy seen just 330 million years after the Big Bang. It is the fifth most distant galaxy ever observed and, according to lead author Joris Witstok, a postdoctoral researcher at the Cosmic Dawn Center at the University of Copenhagen, it is also the earliest galaxy caught in the act of clearing the cosmic fog.

JWST spotted the galaxy, called JADES-GS-z13-1, shining brightly at a specific wavelength called Lyman-alpha, which is highly susceptible to absorption by neutral hydrogen. That this light is visible, then, means the galaxy has ionized the surrounding hydrogen to a far greater extent than expected this early in the universe's history. JADES-GS-z13-1 appears to have cleared a region around itself some 650,000 light-years across.

Exactly how it's done so, though, is still a mystery. Astronomers aren't sure whether the Lyman-alpha photons are from an accreting central black hole or a population of hot stars — perhaps some of the very first stars that ever formed,



Over its first three years of operation, the Dark Energy Spectroscopic Instrument has mapped nearly 15 million galaxies, shown in this plot as two fans, above and below the plane of the Milky Way.
DESI COLLABORATION/DOE/KPNO/NOIRLAB/NSF/AURA/R. PROCTOR

3 Dark energy could be changing

It has been nearly three decades since the stunning discovery that the universe's expansion is accelerating. Scientists refer to the unknown force driving this phenomenon as dark energy, and its nature remains one of the cosmos' great mysteries.

In a fresh twist, the Dark Energy Spectroscopic Instrument (DESI) on the 4-meter Mayall Telescope at Kitt Peak National Observatory in Arizona is chipping away at the long-held notion that dark energy is a constant, unchanging force throughout cosmic history. Instead, it may be evolving, weakening over time.

The results are not definitive, but they are gathering momentum. The DESI team — made of more than 900 researchers worldwide — had already announced hints of evolving dark energy in 2024. But in 2025, those hints became hard to ignore.

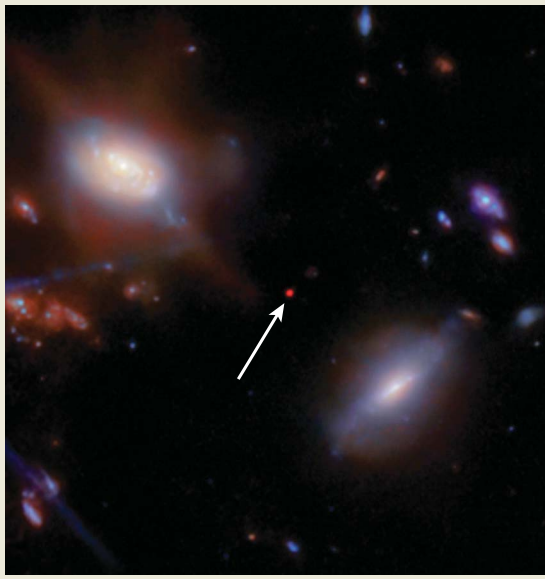
On March 19, in a flurry of papers, the team reported analysis of their first three years of data, which includes nearly 15 million galaxies in the largest 3D map ever made of the universe, spanning 11 billion years of its 13.8-billion-year history. On their own, the DESI results can be squared with the standard model of cosmology, called Lambda-Cold Dark Matter (ΛCDM). But when combined with results from other methods of measuring the universe's expansion, discrepancies emerge. Depending on the datasets chosen, statistical significances range from 2.8 to 4.3 sigma — approaching, at the high end, the widely accepted 5-sigma standard for a definitive result. "What we're seeing is deeply intriguing," said Alexie Leauthaud-Harnett, a cosmologist at the University of California, Santa Cruz, in a statement.

In the ΛCDM model, dark matter is represented by Λ, also known as the cosmological constant, a term first introduced by Albert Einstein. For some astronomers, the idea that the cosmological constant may not be constant after all is hard to stomach.

But for others, a dynamic dark energy is thrilling, opening new theoretical avenues. The simplest theoretical form of an evolving dark energy posits that it is simply weakening over time according to a power-law or exponential decay. But more exotic theories like gravity changing across time and space or interactions between dark energy and dark matter are also on the table.

which have not yet been directly observed. "This fascinating emission line has huge ramifications for how and when the universe reionized," said study co-author Kevin Hainline, from the University of Arizona, in a press release, as determining the source of JADES-GS-z13-1's UV photons will help pinpoint the mechanisms responsible for reionization across the cosmos. Regardless of the cause, the team writes that the discovery "readily constrains the timeline of cosmic reionization, favoring an early and gradual process driven (initially) by low-mass galaxies," as JADES-GS-z13-1 appears fainter and less massive than other galaxies at similar or even greater distances — none of which show the same signature, meaning they are likely still shrouded in neutral hydrogen.

For now, JADES-GS-z13-1 is unique. But Witstok says the search for more galaxies like it is ongoing. As more are found, astronomers will gain a better understanding of how these lights in the darkness ultimately cleared the view for us to peer across the universe unhindered today.



The distant galaxy JADES-GS-z13-1 appears here as a tiny, unassuming red dot at the center of the image. But this young galaxy, which existed when the universe was just 330 million years old, is the earliest galaxy ever seen beginning to clear the cosmic fog and end the era known as the Dark Ages. IMAGE: NASA, ESA, CSA, JADES COLLABORATION, BRANT ROBERTSON (UC SANTA CRUZ), BEN JOHNSON (CFA), SANDRO TACCHELLA (CAMBRIDGE), PHILL CARGILE (CFA), JORIS WITSTOK (CAMBRIDGE, UNIVERSITY OF COPENHAGEN), P. JAKOBSEN (UNIVERSITY OF COPENHAGEN), ALYSSA PAGAN (STSCI), MAHDI ZAMANI (ESA/WEBB)

Astronomers rally against NASA, NSF cuts

The first days of President Donald Trump's second administration were a shock to the scientific system. After Trump took office Jan. 20, scientists spoke in interviews of a climate of fear and anxiety as the Office of Management and Budget froze grants and paychecks, and NASA scrambled to scrub content related to diversity programs from its website.

Both NASA and the National Science Foundation (NSF) were early targets of Elon Musk's Department of Government Efficiency initiative, with deep staffing cuts eventually enacted at NSF. While NASA avoided mass layoffs, White House directives to reduce workforce led to around 20 percent of employees taking voluntary buyouts.

More tumult arrived in spring, when the White House's 2026 budget request to Congress proposed reducing NASA's budget by 24 percent. While its human exploration directorate would receive an 8 percent funding boost, its science directorate would see a budget cut of 47 percent, shuttering or severely downsizing dozens of operational missions and canceling several future ones. The request also proposed a 56 percent cut to NSF, the biggest supporter of U.S. ground-based astronomy.

The impacts would be devastating, researchers warned. Multiple professors told *Astronomy* they were especially concerned about impacts on students and postdoctoral researchers, including those for whom speaking out might jeopardize their U.S. immigration status. And with the funding uncertainty, they said U.S. students are increasingly looking abroad for careers — or leaving the field entirely.

The unprecedented proposed cuts prompted a flurry of action from the community. Through rallies, open letters, and outreach to Congress, researchers and organizations raised their voices, warning of a loss of U.S. competitiveness and leadership in science. In July, all seven living former NASA science chiefs spoke out in a joint letter, while hundreds of NASA employees signed the so-called Voyager Declaration dissenting to the cuts. And a score of national organizations rallied on Capitol Hill Oct. 6 to "save NASA science" by seeking to hold funding at current levels.

Maryland Democratic Congressman Glenn Ivey (right) looks on as Planetary Society CEO Bill Nye speaks at a rally Oct. 6, 2025, seeking to preserve science funding for NASA and the National Science Foundation. THE PLANETARY SOCIETY

Through the summer and into the fall, Senate appropriators sided with researchers; their science spending bill, introduced in July, rejected nearly all of Trump's NASA and NSF cuts. The House appropriations committee held NASA's overall budget flat, but cut its science directorate by 18 percent, redirecting much of that to human exploration; it also recommended a 23 percent cut to NSF.

Neither chamber passed a budget before the start of the 2026 fiscal year on Oct. 1, leading to a government shutdown that ended Nov. 12.

1

The Vera C. Rubin Observatory opens its dome

On June 23, the Vera C. Rubin Observatory released its first images to great fanfare. Viewers around the world streamed the press conference from schools, museums, and planetariums, marveling at expansive nebulae and packed fields of galaxies in exquisite detail. Additionally, the observatory released movies of moving asteroids and twinkling stars to highlight its ability to chart the cosmos in real time.

Located in Chile and jointly funded by the National Science Foundation and U.S. Department of Energy (DOE), the project originally known as the Large Synoptic Survey Telescope (LSST) began construction in 2015. In 2019 it was renamed for astronomer Vera Rubin (1928–2016), whose work charting the rotation of galaxies was instrumental in the discovery of dark matter. It houses the 8.4-meter Simonyi Survey Telescope, whose three-mirror design guides light into the 3,200-megapixel LSST Camera — the largest digital camera in the world. It can cover some 9.6 square degrees, the area of 45 Full Moons, in one shot. Displaying a single image at full size would require 400 4K-resolution TVs.

The observatory's 10-year survey of the Southern Hemisphere sky is called the Legacy Survey of Space and Time. It will image nearly the entire southern sky every three to four days, taking some 1,000 images per night. An average field will receive 800 30-second visits over 10 years, amounting to some 6.7 hours of total exposure time, with select regions seeing up to 1,100 visits (9.2 hours total exposure time). The result: 20 terabytes of data each night, and some 60 petabytes of raw data and 500 petabytes of processed, calibrated data at the end of 10 years.

"This observatory represents a giant leap in our ability to explore the cosmos and unwrap the mysteries of the universe," said Kathy Turner, U.S. DOE program manager for the observatory, during the first-look press conference.

Rubin has four main science goals: to understand dark matter and dark energy, to inventory the solar system's small bodies, to map the Milky Way, and to discover and track astronomical transients. By mapping 20 billion galaxies, as well as studying effects such as gravitational lensing — the bending of light from distant objects by foreground galaxy clusters — Rubin will trace out the structure of the universe, which is dictated in large part by the distribution of dark matter and the influence of dark energy. Charting billions of stars in the Milky Way and its satellites will help illuminate the nature and history of our home galaxy.

Rubin will also create a high-definition movie of the sky to catch billions of events ranging from exploding supernovae and snacking black holes to transiting planets and never-before-seen asteroids and comets. Transients are flagged and a real-time,

ABOVE: The Vera C. Rubin Observatory sits atop Cerro Pachón, Chile, beneath the starry Southern Hemisphere sky. The plane of the Milky Way arcs above the observatory; the Large and Small Magellanic Clouds appear at left. Rubin will survey nearly the entire southern sky every three to four days for the next decade.
NSF–DOE RUBIN OBSERVATORY/P.J. ASSUNCAO LAGO

LEFT: These images were among the first released by the Vera C. Rubin Observatory. At far left is a nearly 5-gigapixel, 678-exposure composite of the Trifid and Lagoon nebulae (M20 and M8, respectively) totaling 7.2 hours of exposure time. At immediate left is a 1,185-shot composite of the Virgo Cluster taken over about 10.5 hours. Visible are some 10 million galaxies, many of which are not part of the cluster but lie far beyond it. All the galaxies in this image represent just 0.05 percent of the 20 billion total galaxies Rubin will capture in its 10-year survey.
NSF–DOE VERA C. RUBIN OBSERVATORY (2)

public alert is issued within 60 seconds: Up to 10 million alerts will go out per night. With an archive of past images over time, "if something strange appears — an explosion, an object vanishing — we can rewind and see what led up to it," said Yusra AlSayyad, who manages the observatory's image-processing algorithms, in a press release.

Astronomers must often balance the need for long exposures to view faint or faraway objects with scanning the sky to serendipitously catch new events. Both goals are now achievable simultaneously with Rubin.

The Vera C. Rubin Observatory is a "tremendous technological achievement" that "truly will bring an understanding of our universe simply not possible before," said Secretary of Energy Chris Wright during the press conference. "The movie is started, the camera is running, and we're going to see our cosmos unfold before us."

Alison Klesman *is senior editor,* **Brooks Mendenhall** *is staff writer, and* **Mark Zastrow** *is editor-in-chief of* Astronomy. *They look forward to what 2026 holds.*

STORIES TO WATCH FOR IN 2026

1 NASA's Artemis 2 mission, which will send four astronauts around the Moon in the first manned lunar flight since Apollo 17, is scheduled to launch no later than April 2026.

2 SpaceX's Starship will need to refuel in space to reach the Moon or Mars. The Propellant Transfer Demonstration Mission, which will demonstrate this ability by docking two Starships in low Earth orbit to transfer fuel between them, is expected to occur in 2026.

3 NASA is planning to launch the Nancy Grace Roman Space Telescope, the agency's next major space observatory, as early as fall 2026.

4 The next launch window for Mars will open in November 2026. NASA has announced it may use the opportunity to launch a mission that will test technology for future human landings there.

5 The Japanese Martian Moons eXploration (MMX) mission, which will return samples from Mars' moon Phobos, is also scheduled to take advantage of the late 2026 launch window for Mars.

6 ESA's Hera mission arrives at the binary asteroid Didymos and Dimorphos Dec. 14, 2026. Dimorphos was struck by NASA's Double Asteroid Redirection Test (DART) spacecraft in 2022, altering its orbit; Hera will survey the aftermath up close.

7 The Rocky Worlds Director's Discretionary Time program, which combines JWST and Hubble observations to search for atmospheres on rocky exoplanets that orbit M-dwarf stars, will continue through at least mid-2026.

TOP TO BOTTOM: NASA; SPACEX; NASA GODDARD SPACE FLIGHT CENTER SCIENTIFIC VISUALIZATION STUDIO; NASA/USGS; JAXA; ESA – SCIENCE OFFICE; NASA, ESA, CSA, DANI PLAYER (STSCI)

SKY THIS MONTH

Visible to the naked eye
Visible with binoculars
Visible with a telescope

THE SOLAR SYSTEM'S CHANGING LANDSCAPE AS IT APPEARS IN EARTH'S SKY.
BY MARTIN RATCLIFFE AND ALISTER LING

Jupiter (bottom center) rises beneath a colorful auroral curtain in February 2018, as seen from Churchill, Manitoba. ALAN DYER

Jupiter remains king

Mercury, Venus, and Saturn put on an early-evening display in the west, while Jupiter dominates the rest of the night. Jupiter features many events involving its four major moons that are well worth chasing down. A remote annular eclipse of the Sun occurs on the 17th, visible only from Antarctica.

Mercury puts in a fine evening appearance during February. It reaches greatest eastern elongation 18° from the Sun on Feb. 19. With the high angle of the ecliptic to the western horizon after sunset, this places Mercury more favorably than at other times in the year. Watch the western sky as it darkens for the innermost planet.

Your first view might occur Feb. 10, when Mercury stands about 7° above the western horizon 30 minutes after sunset. At magnitude –1.1, it's bright enough to punch through early-evening twilight. Some observers with a western horizon free of obstructions might also spot magnitude –3.9 **Venus** 1° high. Mercury sets shortly before 7 P.M. local time.

Mercury appears higher each subsequent evening as it climbs toward greatest elongation. On the 13th, it sets 80 minutes after the Sun. Grab some binoculars and see if you can spot the star Lambda (λ) Aquarii (magnitude 3.7) just 16′ from the planet. Magnitude 1.0 Saturn stands higher in the western sky and becomes visible as the sky darkens.

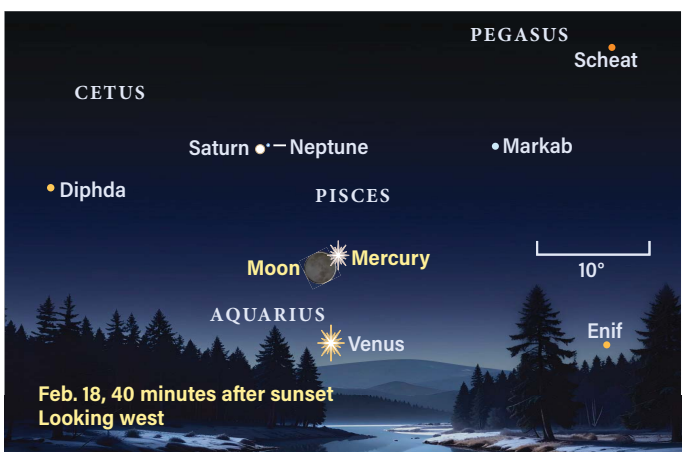
On Feb. 18, a 1.5-day-old crescent Moon joins Mercury in the western sky. Their relative positions change as twilight progresses across the U.S. East Coast observers see Mercury north of the Moon. By dusk on the West Coast, the Moon is almost 1° east of Mercury. Bright Venus hangs below them.

Lucky observers located along a narrow corridor of southern states (Arizona, New Mexico, Texas, Louisiana, Mississippi, and Georgia) will see Mercury disappear behind the Moon in an occultation. See http://lunar-occultations.com for local timing.

Later in the month, Mercury drops in elongation from the Sun as well as in magnitude as it heads toward an early March inferior conjunction. Meanwhile, Venus is rising higher. Feb. 23 finds the two planets 6° apart. Venus is 4° high 30 minutes after sunset and you'll find Mercury, at magnitude 0, northeast of Venus.

Mercury stands less than 5° due north of Venus on the 26th; Mercury has now dimmed significantly to magnitude 0.8. Saturn is now 10° west of Mercury. On Feb. 28, Venus and Mercury stand side by side 4.8° apart, though Mercury is now magnitude 1.5. The pair sets an hour after the Sun. It will be hard to track Mercury after this date.

The place to be



The western sky holds several planets after sunset midmonth. On Feb. 18, a thin crescent Moon joins in as well — some observers will see it occult Mercury. Note that Neptune is not visible to the naked eye. ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

OBSERVING HIGHLIGHT

THE MOON occults **MERCURY**
Feb. 18, visible along a narrow corridor in the southern U.S.

Saturn lingers in the western sky after dark. It resides in the constellation Pisces. Catch it early in February for good telescopic views. It stands about 30° high in the southwestern sky an hour after sunset on Feb. 1, shining at magnitude 1.0. By the 14th its altitude has dropped to 20° one hour after sunset. Telescopic observations become increasingly difficult later in the month due to atmospheric turbulence affecting the planet at low altitudes. By the end of February, Saturn stands only 7.5° high in the west an hour after sunset. It reaches conjunction with the Sun in late March.

— *Continued on page 34*

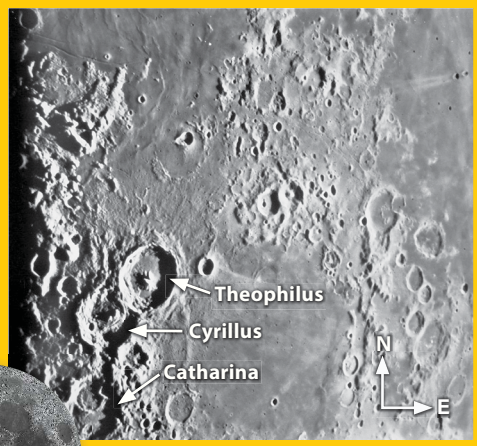
RISING MOON | Terrific trio

IT'S A SMORGASBORD of fantastic views on the crescent Moon as it grows from the slenderest of arcs to a half-illuminated disk. The terminator zone straddling day and night is chock-full of rolling seas bordered by craters with towering peaks and aprons of debris. On Feb. 22, our focus is to the south, but never throw away a chance to first enjoy the Serpentine Ridge snaking across the large Sea of Serenity in the north.

Immediately south of the lunar equator, a terrific trio of craters grabs the eye. Theophilus is the most classic of the three: Its rim is sharp, almost perfectly circular, and sports a dramatic multiple central peak. Because it is much bigger and deeper than smaller Mädler immediately to the east, the walls of Theophilus slumped into terraces that are most noticeable on the western flank.

You can make some pretty good guesses at the relative age of a feature without needing the sharper tools of a lunar geologist. Theophilus must be the youngest because it overlays the ragged rim of the crater to the southwest. Cyrillus too has a complex peak and slumped walls, but they are degraded from the impacts of smaller objects as it aged. Plopped all around Theophilus in an apron, the impact ejecta partially fills neighboring Cyrillus. The rough texture is really obvious at this phase. Under a high Sun at Full Moon, this topographic detail vanishes, leaving just the ring of the rim for identification. Mädler seems to shelter the terrain to the east from the debris, hinting at an intermediate age.

Theophilus, Cyrillus, Catharina



This trio of craters shows its members' varying ages to the keen-eyed observer.
CONSOLIDATED LUNAR ATLAS/UA/LPL. INSET: NASA/GSFC/ASU

The southernmost of the trio is Catharina, undoubtedly once sharp-featured like Theophilus, but millions of years of bombardment have erased the central peak and left its walls softer and lower.

Return to observe March 23 when the Sun is lower in the lunar sky, producing longer shadows that exaggerate the apparent heights. To the trio's southeast in the Sea of Nectar is a wrinkle ridge that formed when the lunar crust was slowly compressing, leaving the ground nowhere to go but buckle upward, just like the Serpentine Ridge north of the equator.

METEOR WATCH | Sky lights

Dark sky, soft glow

The soft glow of the zodiacal light appears over Georgia's Lake Tobesofkee in early 2016. STEPHEN RAHN

MAJOR METEOR SHOWERS skip February altogether. Random or sporadic meteors from ancient streams long since dispersed produce about a half-dozen meteors per hour. Meteors are always best seen after midnight under a dark, moonless sky. In the runup to dawn, you're sitting on Earth's leading hemisphere as it orbits the Sun, resulting in higher velocities as any cometary detritus enters the atmosphere.

Also visible on moonless evenings in February is the zodiacal light. This dim glow, aligned with the ecliptic, extends steeply above the western horizon well after the low arc of the twilight glow has diminished. From completely dark locations, the zodiacal light is almost as bright as the Milky Way. The cone extends upward through Aquarius, Pisces, and Aries. A line connecting Mercury and Saturn shows the way.

Scan your eyes left and right and your peripheral vision will pick up the cone-shaped glow. The middle of the month, starting after Feb. 6, is the best time to look, with the bright Moon out of the evening sky.

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

10 P.M. February 1
9 P.M. February 15
8 P.M. February 28

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**

FEBRUARY 2026

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

1 Full Moon occurs at 5:09 P.M. EST

2 The Moon passes 0.4° north of Regulus, 10 P.M. EST

3 Uranus is stationary, midnight EST

9 Last Quarter Moon occurs at 7:43 A.M. EST

10 The Moon is at apogee (251,392 miles from Earth), 11:52 A.M. EST

The Moon passes 0.7° south of Antares, 11 P.M. EST

15 The Moon passes 0.9° north of Pluto, 10 A.M. EST

Saturn passes 0.9° south of Neptune, 11 P.M. EST

17 New Moon occurs at 7:01 A.M. EST; annular solar eclipse

18 The Moon passes 1.7° north of Venus, 4 A.M. EST

The Moon passes 0.1° south of Mercury, 6 P.M. EST

19 Mercury is at greatest eastern elongation (18°), 1 P.M. EST

The Moon passes 4° north of Neptune, 7 P.M. EST

The Moon passes 5° north of Saturn, 7 P.M. EST

23 The Moon passes 6° north of Uranus, 8 P.M. EST

24 First Quarter Moon occurs at 7:28 A.M. EST

The Moon is at perigee (229,991 miles from Earth), 6:14 P.M. EST

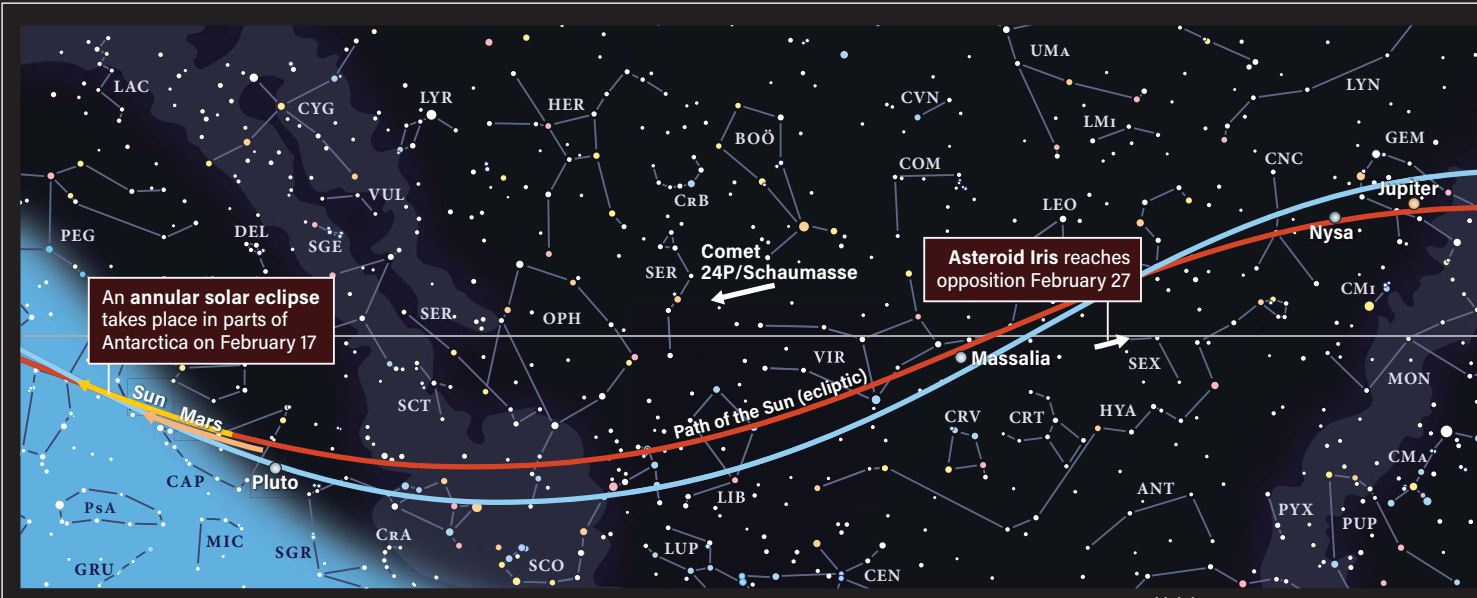
25 Mercury is stationary, noon EST

26 Mercury passes 5° north of Venus, 6 P.M. EST

27 The Moon passes 4° north of Jupiter, 1 A.M. EST

Asteroid Iris is at opposition, 1 P.M. EST

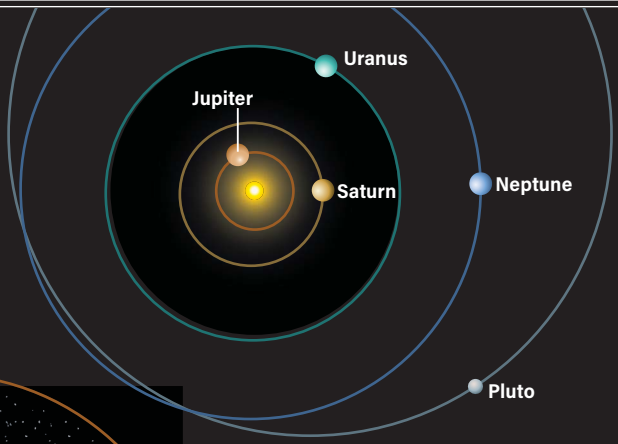
PATHS OF THE PLANETS

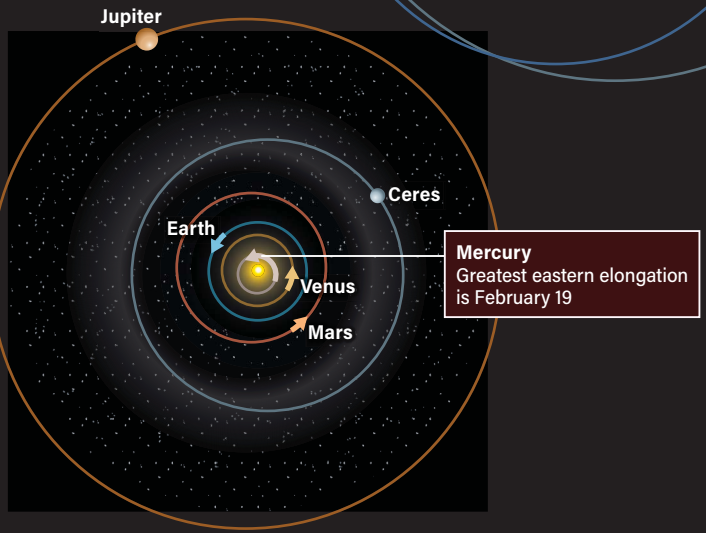


To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

THE PLANETS IN THEIR ORBITS

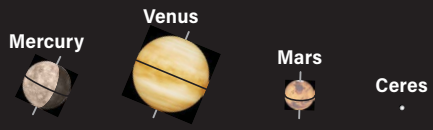
Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at midmonth from high above their orbits.





THE PLANETS IN THE SKY

These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets at 0h UT for the dates in the data table at bottom. South is at the top to match the view through a telescope.



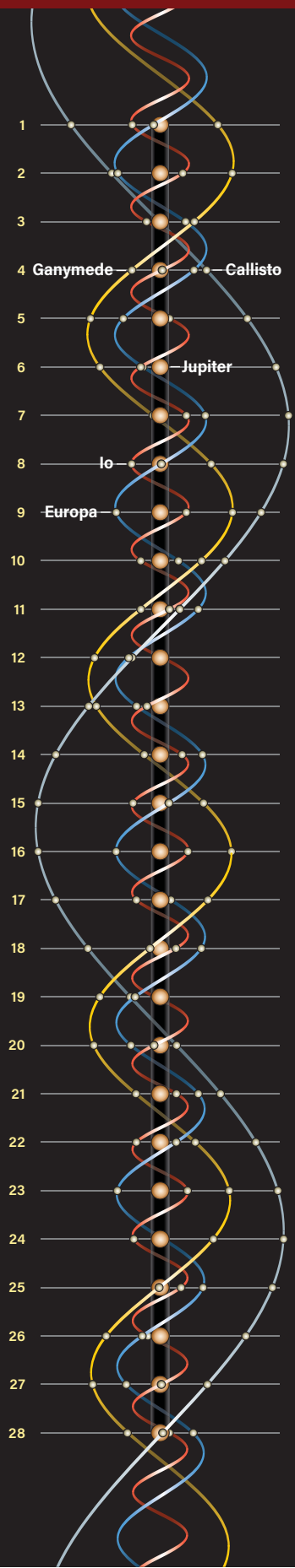
PLANETS	MERCURY	VENUS
Date	Feb. 15	Feb. 28
Magnitude	–0.9	–3.9
Angular size	6.3"	10.1"
Illumination	70%	98%
Distance (AU) from Earth	1.069	1.659
Distance (AU) from Sun	0.314	0.726
Right ascension (2000.0)	22h56.9m	23h31.3m
Declination (2000.0)	–6°40'	–4°35'

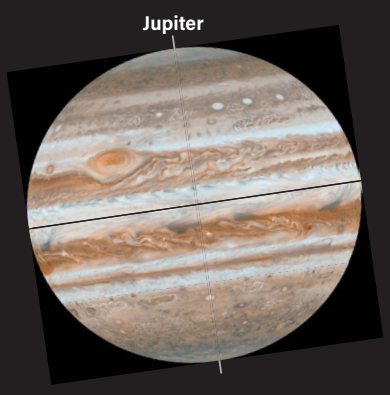
This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

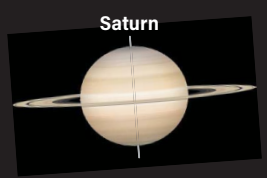
FEBRUARY 2026

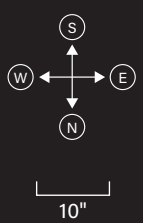
JUPITER'S MOONS

Dots display positions of Galilean satellites at 11 P.M. EST on the date shown. South is at the top to match the view through a telescope.









Uranus Neptune Pluto

MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Feb. 15	Feb. 15	Feb. 15	Feb. 15	Feb. 15	Feb. 15	Feb. 15
1.1	9.1	−2.5	1.0	5.7	7.8	15.2
4.0"	0.4"	44.4"	16.1"	3.6"	2.2"	0.1"
100%	98%	100%	100%	100%	100%	100%
2.361	3.326	4.436	10.309	19.436	30.695	36.363
1.392	2.856	5.228	9.505	19.482	29.884	35.452
21h20.6m	1h21.5m	7h08.1m	0h02.5m	3h39.6m	0h02.8m	20h28.2m
−16°40'	1°41'	22°51'	−2°04'	19°20'	−1°07'	−23°02'

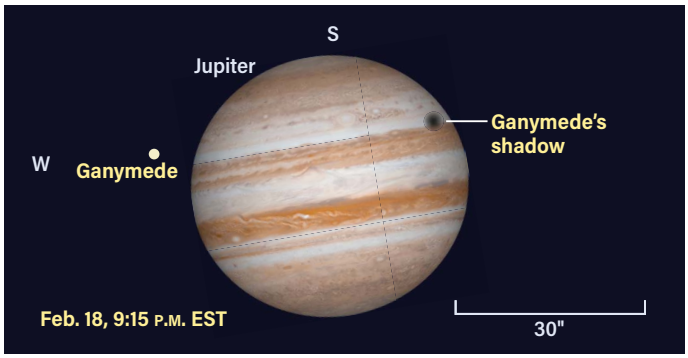
 — Continued from page 29

WHEN TO VIEW THE PLANETS

EVENING SKY
Mercury (west)
Venus (west)
Jupiter (east)
Saturn (west)
Uranus (south)
Neptune (west)

MIDNIGHT
Jupiter (west)
Uranus (west)

Shadow trailing



Shortly after 9 P.M. EST on Feb. 18, Ganymede has completed a transit and its shadow has appeared on Jupiter's cloud tops for a transit of its own. Callisto is to the west, while Io and Europa lie to Jupiter's east, outside this field of view.

Neptune lies within 1.8° of Saturn all month and becomes increasingly difficult to observe at lower altitudes as February progresses. Try so spot it in the first half of February. On Feb. 15, Neptune stands 0.9° due north of Saturn, within the same low-power field of view in many telescopes. It shines at magnitude 7.8, easily within range of binoculars.

Uranus returns to easterly motion after the 3rd, starting February 5° south-southwest of the Pleiades (M45). On Feb. 1, Uranus stands 0.7° southwest of the 6th-magnitude star 13 Tauri. Any motion back toward this star isn't noticeable until the second week of the month. A waxing Moon passes across the northern limits of M45 on the 23rd, when Uranus lies 0.6° from 13 Tau. The planet draws to within 0.5° of the star by the 28th.

Through a telescope, Uranus reveals a pale greenish disk spanning 4". Observers with experience in high-speed video capture of planets might want the challenge of recording Uranus while it is high in the sky soon after sunset.

Jupiter is visible all night after passing through opposition last month. It starts the month at magnitude –2.7 among the stars of Gemini the Twins.

Jupiter's disk — 46" wide as the month opens — offers a lot of detail in telescopes of almost any size. Two dark belts straddling the equator are most obvious. Look for subtle features along their edges, such as dark material encroaching into the adjacent white zones. The planet rotates quickly, with the equatorial regions completing one rotation in nine hours and 50 minutes, and higher latitudes taking five minutes longer.

Occasionally you'll see the Great Red Spot along the southern edge of the South Equatorial Belt. If it's not visible when you look in the evening, try again a few hours later. It's bound to come into view sooner or later.

Jupiter's four largest moons — Io, Europa, Ganymede, and Callisto — dance around the planet in ever-changing positions with periods ranging from two to nearly 17 days. February offers a full series of transits, occultations, and shadow transits. These events are an exercise in visualizing orbital motion: Inner moons move faster than outer ones, and resonant orbits produce repeating events.

With Jupiter now past opposition, during satellite and shadow transits the moon transits first, followed by its shadow. By now, the gap between these events is wider than in January.

The first evening of February hosts a transit of Europa. Europa begins to transit at 7:37 P.M. EST, followed by its shadow at 8:42 P.M. EST. Similar events occur on Feb. 8 and 15/16, at progressively later times in the evening. On the

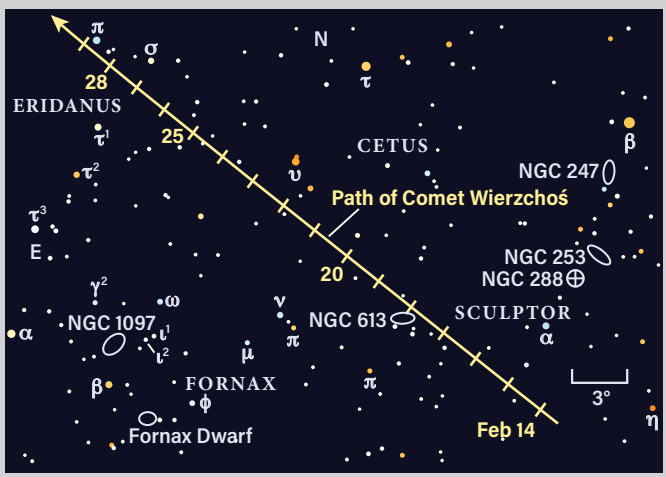
COMET SEARCH | Lower latitudes lead

THE VIP COMET this month is 6th-magnitude C/2024 E1 (Wierzchoś). After a nice showing in the south, this month it fades gracefully for northern observers, last to the viewing party. Visible to the unaided eye south of the equator from a dark site, the comet pales into binocular range by the second week of February for the Gulf States. It's midmonth by the time it climbs high enough to be seen in deep evening twilight from the Great Lakes.

Do your best to ignore the waxing Moon and go to medium power to uncover details. Having just passed its closest approach to the Sun (perihelion) Jan. 20 and now halfway between the orbits of Mercury and Venus, the core will be active. Because the shroud of expelled dust hides the comet's surface, the bright spot we see is called the false nucleus.

Compare Wierzchoś to 24P/Schaumasse, last month's featured comet, located in the morning sky. In contrast to Schaumasse's round inner core, Wierzchoś will be decidedly ungalaxylike. The east and north flanks will be sharp where the solar wind blows away the gas and dust tails. The softer glow of the tilted fan fades into the west.

Comet C/2024 E1 (Wierzchoś)



This chart shows the path of Comet Wierzchoś in the second half of February. Only deep-sky objects brighter than 10th magnitude are shown. For details on the comet's position earlier in the month, visit our website.

Passing through

By 7:30 P.M. CST on Feb. 23, the Moon is preparing to pass in front of a portion of the Pleiades. Uranus — which will require optical aid — is also in Taurus. You will need magnification to spot Neptune, near Saturn, as well.

8th, Europa's transit begins at 9:54 P.M. EST, then at 12:15 A.M. EST on the 16th (in the Eastern time zone only, still the 15th farther west). Its shadow follows 83 and 99 minutes later, respectively, on these nights.

Callisto disappears behind the northwestern limb of Jupiter Feb. 3 at 9:34 P.M. EST. One and a half orbital revolutions later, on Feb. 28, Callisto begins a transit in front of Jupiter around 10:20 P.M. EST.

Io orbits Jupiter every 42.5 hours and produces many events. On the 4th, Io begins a transit at 10:20 P.M. EST, followed by its shadow 35 minutes later. Note that the separation between transits of Io and its shadow is smaller than for Europa. Why? Europa is in a larger orbit, so lies farther from Jupiter.

Io transits again Feb. 11/12 at 12:06 A.M. EST (the 12th in EST only), and again Feb. 18/19 beginning at 1:54 A.M. EST on the 19th.

Ganymede is the largest moon and thus casts the largest shadow on Jupiter. U.S. East Coast observers will see Ganymede's shadow on Jupiter as darkness falls on Feb. 11.

On the evening of Feb. 18, East Coast viewers see a transit underway as soon as it's dark. Ganymede takes just over three hours to cross the disk of Jupiter. It leaves the disk by 5:44 P.M. PST, roughly sunset on the West Coast. But there's more to come — the giant shadow begins a transit some 10 minutes after the moon clears the disk. Watch the southeastern limb for the black notch beginning to grow. A few minutes after 9 P.M. EST, the shadow is fully on Jupiter's disk and it, too, takes a bit more than three hours to cross.

Ganymede repeats its transit on the 25th at 8:55 P.M. EST, and its shadow appears exactly four hours later.

You can see Ganymede disappear behind Jupiter's northwest limb earlier in February. Look on the evening of Feb. 7/8 starting at 12:02 A.M. EST, as the giant moon is gradually hidden behind the planet. This event is visible across the continental U.S.

Mars is just past its superior conjunction with the Sun and isn't visible this month.

There's an annular eclipse of the Sun Feb. 17 with limited viewing. The track crosses a portion of Antarctica's icy expanse. A small partial eclipse is visible from southern Africa and Madagascar. An annular eclipse occurs when the Moon is near apogee and doesn't quite cover the Sun at maximum eclipse, leaving a brilliant ring of sunlight, called an annulus — hence the name of this type of eclipse.

Martin Ratcliffe *is a planetarium professional with Evans & Sutherland and enjoys observing from Salt Lake City.* **Alister Ling**, *who lives in Edmonton, Alberta, is a longtime watcher of the skies.*

GET DAILY UPDATES ON YOUR NIGHT SKY AT **www.Astronomy.com/skythisweek.**

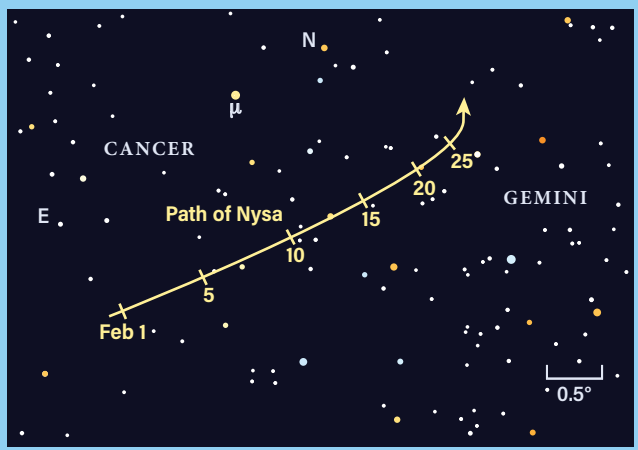
LOCATING ASTEROIDS
A reasonable choice

WHEN AN OBJECT reaches opposition, Earth takes the middle seat between the Sun and our target, forming a nearly straight line. Just past its opposition last month, asteroid 44 Nysa is still reflecting the most light possible, peaking at 9th magnitude this month. It is highest at midnight — somewhat inconvenient for early-evening stargazers — but it's easy to locate, just two finder fields from Pollux if you head away from Castor. You'll find it just south of 5th-magnitude Mu^2 (μ^2) Cancri.

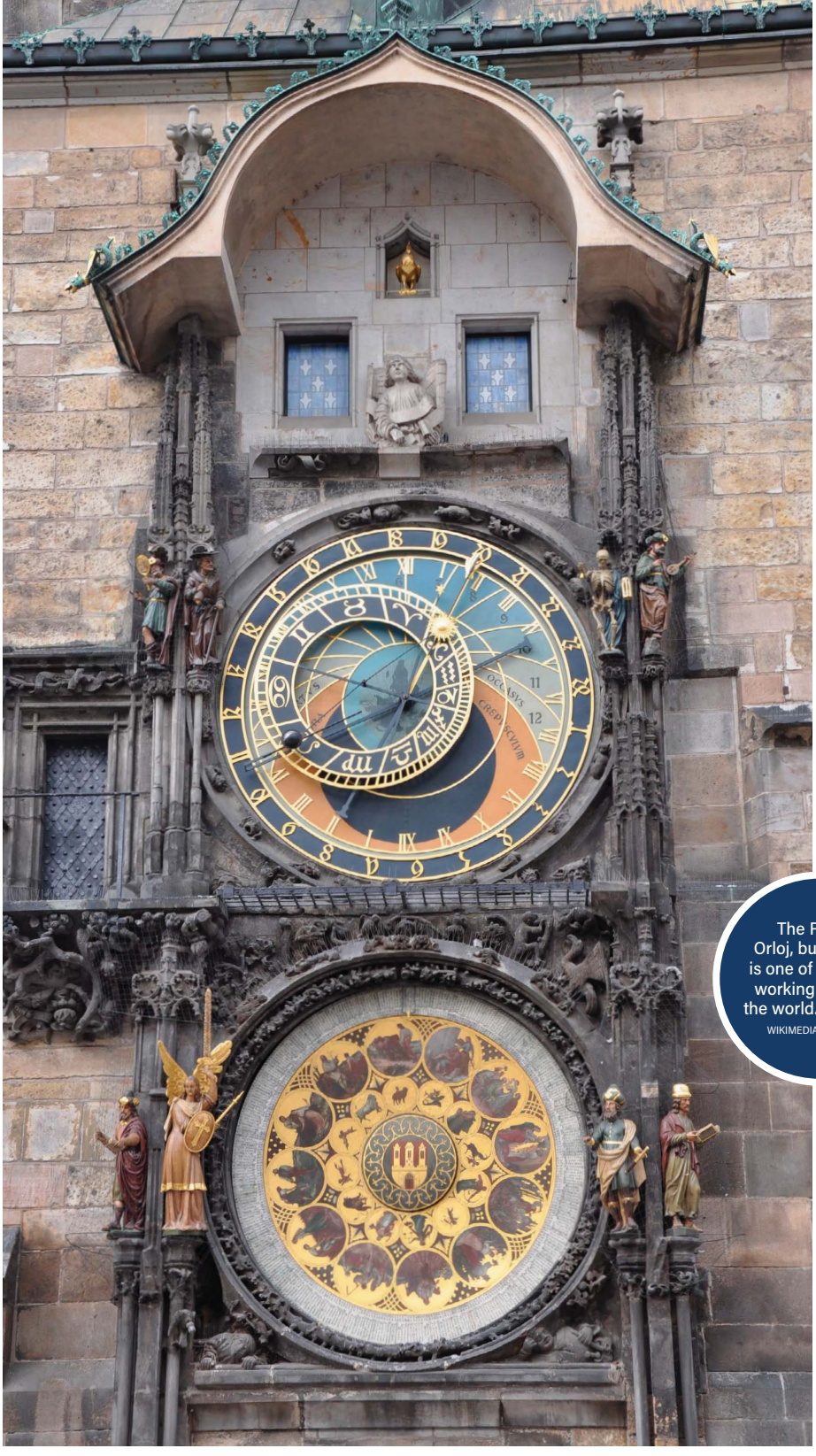
Nysa is a modest dot from the suburbs in a 3-inch scope, yet easier than neighboring field stars on the 1st. By the 6th it lies close to one of two brighter field stars. From the 11th through the 13th, Nysa slides through an extended quad of stars, then enters a notably different array for the last week of the month. Any of these mini-encounters is perfect for sketching its night-to-night displacement.

It took almost 50 years from Giuseppe Piazzi's 1801 discovery of 1 Ceres rack up 20 known asteroids. German astronomer Hermann Goldschmidt found 21 Lutetia in 1852 and Nysa in 1857, two in a prodigious haul of 13 in less than 10 years. He meticulously updated star charts and noted any changes, also discovering variable stars along the way.

Plenty of neighbors



Nysa tracks past several field stars in Cancer and Gemini this month, located near Mu^2 Cancri (labeled simply μ in the chart above).



The Prague Orloj, built in 1410, is one of the oldest working clocks in the world. JORGE LÁSCAR/ WIKIMEDIA COMMONS

TOUR EUROPE'S GREAT CELEST

Got some time on your hands? Visit one of these horological masterpieces.

BY RAYMOND SHUBINSKI

ALL LIVING CREATURES are affected by the cycles of celestial objects. Humans have always been locked into the rhythms of sunrise and sunset, the phases of the Moon, and the seasons. We left some of this behind by lighting the night and becoming urbanized. But astronomical clocks captured those rhythms by displaying the movements of the heavens, regulating our lives by tracking and dividing the day, months, and years. For centuries, these analog devices served us well.

With no gears or moving hands, but rather a gnomon that projects a shadow on a dial plane to measure the passage of time at a specific location, sundials are the essence of an astronomical timekeeper. The Sun reaching the midpoint of its daily trip across the sky was the first important division of the day. Later, the day was divided into hours. These simple timekeepers remained important until the mid-19th century, long after the mechanical clock rose to dominance; today, these astronomical "clocks" have become garden ornaments.

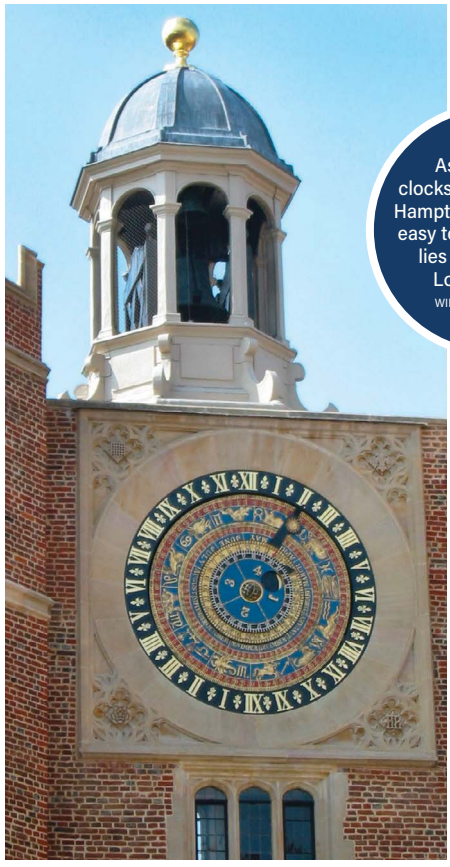
A thousand years ago, the brilliant Chinese engineer Su Song designed and built one of the earliest astronomical clocks on record. The 40-foot (12 meters) tower was filled with gears that were turned by hydraulic power. On the top platform, a massive bronze celestial globe was located. (Unfortunately, the clock was dismantled in 1127, so you can't visit it.)

In Europe during the Middle Ages, it was the duty of some unfortunate monk or nun to rise at designated times and ring a bell to call the brothers or sisters to prayer. They were a kind of manual clock. In fact, the word *clock* may derive from the Medieval Latin word *clocca*, meaning "bell." These church bells divided the day into canonical hours – not 1:00, 2:00, 3:00, as we now mark the time, but eight liturgical hours such as Matins, Compline, Lauds, and Vespers. Because the hours were tied to the rising and the setting Sun, they were not uniform throughout the year. And at times, even the most devout monk might oversleep. By the late 11th and early 12th centuries, mechanical systems had taken over the ringing of church bells.

Churches soon added dials and hands to their turrets to indicate the hour for those who passed by. By the late 14th and early 15th centuries, many major European cities commissioned their own magnificent clocks. Along with the time of day, these clocks also displayed a great deal of astronomical information. I've selected three of the greatest of these — plus one modern masterpiece — in the hopes that, if you're anywhere in Europe, you might visit them.

Head to Prague

When Tycho Brahe and his reluctant assistant, Johannes Kepler, arrived in Prague in 1599, they must have marveled at the city's astronomical clock. Built in 1410, the Prague Orloj is located on the wall of the old city hall and is one of the oldest working clocks in the world. Near the end of World War II, the clock was nearly destroyed by Nazi attacks, but three years later, local citizens united to repair it. Over its six centuries of operation, the Orloj has undergone several other bouts of refurbishment and restoration, most recently in 2018. When you visit the city, you can find the clock by walking down a narrow street and turning into a small courtyard.



As with all the clocks in this story, the Hampton Court Clock is easy to reach. This one lies just outside of London. MAN VYI/ WIKIMEDIA COMMONS

For those with the patience to study the dial more closely, there is a great deal of astronomical information (all set for the latitude of Prague): Sunrise and sunset are displayed on the dial, along with seasonal variations in daylight and darkness. The zodiacal locations of the Sun and the Moon are shown, along with the Moon's phase.

The Prague Orloj was more than a tour de force of civic pride. Well into the 18th century, astrology played a major role in daily life. Clocks such the Orloj provided vital astronomical information for making astrological predictions. Tycho's new patron in Prague, Rudolf II, was obsessed with astrology, and Tycho and Kepler spent much of their time providing charts and horoscopes to the emperor. If you visit this historic clock, decide for yourself if they consulted it in their astrological efforts.

Just outside London

England's King Henry VIII was a towering figure surrounded by drama and intrigue. One of Henry's favorite residences was Hampton Court Palace. Originally built in 1514 by Cardinal Thomas Wolsey, Archbishop of York, the palace has a massive and unique astronomical clock mounted in the tower of what is now called Anne Boleyn's Gate. With a dial more than 10 feet (3 m) in diameter, it was used for astronomical and astrological purposes and for navigation.

Like the Prague Orloj, the Hampton Court clock shows the time of day on a ring marked in 24-hour increments. This clock has three rotating dials, which

IAL CLOCKS

THE CURRENT CLOCK, WHICH TOWERS 59 FEET (18 M) ABOVE THE FLOOR, IS THE THIRD TO GRACE THE CATHEDRAL.

provide the location of the Sun along the zodiac, the phase and age of the Moon, and various calendar functions. The outer dial takes a year to rotate once and shows months and days. The second dial shows the age and phase of the Moon.

Because Hampton Court Palace is located about 12 miles (19 kilometers) from the center of London, Henry's royal court used the River Thames to travel there. This could be dangerous because of the river's tidal flow. However, the clock's central dial provides times when the Moon crosses the meridian. With this information, the boatman knew when it was safe to travel on the river.

You don't need to navigate the Thames, though. You can either drive to the Palace or take the train. From the train station, it's only a five-minute walk.

In eastern France

About 300 miles (482 km) east of Paris is the Cathédrale Notre-Dame in Strasbourg. This is home to one of the most beautiful and complicated astronomical clocks in Europe. The trip from the French capital by train takes less than two hours, and it's totally worth it.

The current clock, which towers 59 feet (18 m) above the floor, is the third to

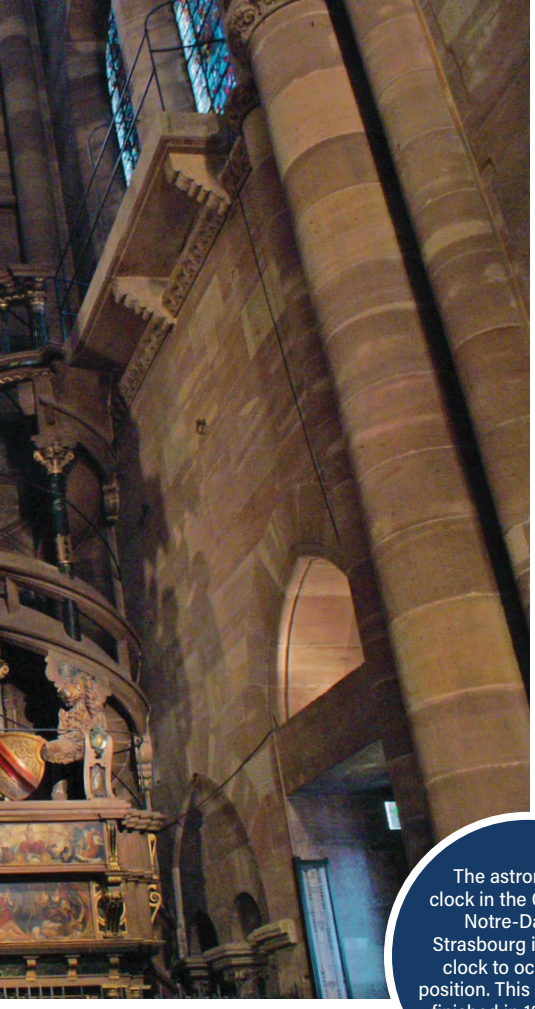
THE ALL-IMPORTANT MOON

Not all astronomical clocks are found on the walls and towers of cathedrals or housed in massive cases. The common grandfather clock is an astronomical clock that can provide celestial information.

While the clocks of Rasmus Sørnes have hundreds of gears, most grandfather clocks only boast 20 or 30 — yet this is sufficient to provide hours, minutes, and seconds, along with chimes that strike every 15 minutes. At the top of the clock face, a rotating dial shows our Moon, tracking the phases of Earth's companion. Today, this little smiling Moon is mostly ornamental. For centuries, however, it served farmers by telling them when to plant their beans or the best time to go fishing.

Many pocket watches were also fitted with Moon phase dials. As with the grandfather clock, this requires an additional gear with 30 teeth linked to the drive gears of the clock or watch. This dial takes a month to rotate once but needs periodic adjusting to account for the Moon's 29.5-day cycle. Some high-end mechanical wristwatches also capture the Moon's movement with tiny dials. A few watch companies even make replicas of these medieval clocks for your wrist. All you need to own one is deep financial pockets. —*R.S.*

Many grandfather clocks incorporate a Moon phase dial. YAROSLAVL ART MUSEUM/WIKIMEDIA COMMONS



The astronomical clock in the Cathédrale Notre-Dame in Strasbourg is the third clock to occupy this position. This version was finished in 1845. DIDIER B/ WIKIMEDIA COMMONS

grace the cathedral. The first clock was built in the 14th century. Little is known about this medieval clock other than it had a mechanical rooster that announced the hours. A second clock was built in the 16th century. It was adorned with an astrolabe dial, a Moon phase indicator, and calendar dials. It could even predict eclipses.

The third clock was finished in 1845 and is a marvel of astronomical complications. A large celestial globe sits at the base of the clock. Behind the globe, a massive dial shows apparent time while a statue of the goddess Diana points to liturgical events on a rotating ring with a golden arrow. As with many astronomical clocks, Moon phases are tracked, the Sun's location along the zodiac is shown, and a perpetual calendar provides the current date. A great deal of additional information is displayed on multiple brass dials. Best of all, there is still an automated rooster.

If you're visiting Norway

Medieval astronomical clocks were complicated and ingenious devices, but pale in comparison to the celestial clocks made by Rasmus Jonassen Sørnes, who began life as a Norwegian farmboy. As a teenager in the early 1900s, Sørnes applied to become an apprentice clockmaker but was turned down because he had big farmer's hands. He eventually became a radio technician but never lost his love for horology.

Shortly before World War II, he began work on a series of astronomical clocks that combined traditional clockmaking techniques with 20th-century technology. His first two clocks appear to have been test runs. Clock No. 3, however, is a masterpiece. A terrestrial and celestial globe are housed at the bottom of a glass and brass case. The terrestrial globe not only revolves once a day but also simulates the precession of the equinox. The stars on the celestial globe are represented by tiny holes lit by an interior lightbulb.

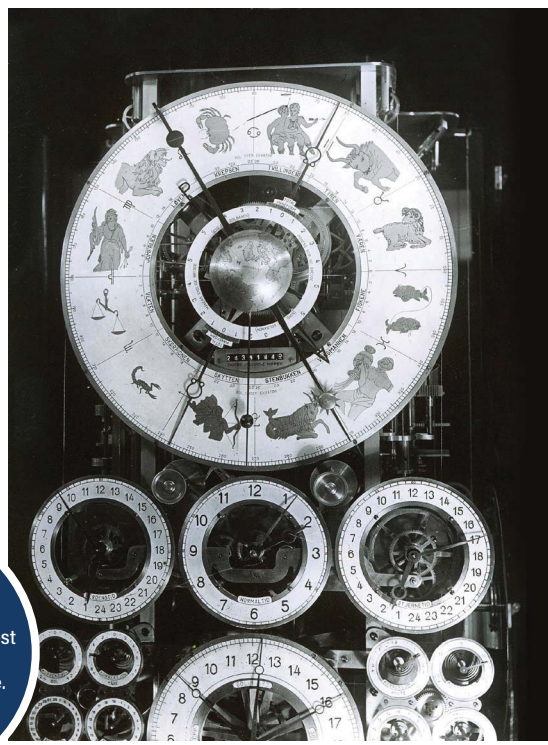
The main dial is engraved with the zodiac constellations. The Sun hand on this dial takes a year to revolve once, while the Moon hand has gears that allow it to speed through the zodiac in a synodic period of 29½ days. This dial also tracks the 18.5-year saros cycle to predict solar and lunar eclipses. (See page 53 for an explanation of the saros cycle.) The clock has 14 additional dials that show calendar dates, local and sidereal time, and a lot more. Sørnes even put a tape recorder in the base of the clock with a narrated presentation about astronomy. You can find the clock in the Borgarsyssel Museum in Sarpsborg, Norway, which lies around 57 miles (91 km) south of Oslo.

In 1966, Sørnes completed a fourth astronomical clock that was even more complex. This was an amazing feat for a self-educated man. Building mechanical clocks of this complexity requires understanding of mathematics, gear ratios, machining and electronics, and astronomy. Almost unknown today, Sørnes may be the greatest maker of astronomical clocks in history. Unfortunately, you can't visit this horological wonder. After being displayed at the Time Museum in Rockford, Illinois, from 1967 to 1999, and at the Chicago Museum of Science and Industry from 1999 to 2002, the clock was acquired by an anonymous buyer. Its location is now unknown.

Time to begin

Today's atomic clocks boast an uncertainty of one second in 300 million years. When you look at their numerical readouts, they tell you the exact moment you are in. What such clocks don't provide can be found on a clock with a dial and hands. Such historical creations show us the astronomical rhythms of nature. These old clocks tell us the time it is now and the time that has slipped away, and point to the future that awaits us. I hope you'll be able to visit one or more soon.

Contributing Editor **Raymond Shubinski** *loves the link between astronomy and timekeeping. He often writes to the ticking sound of his old grandfather clock.*



This clock, by Rasmus Jonassen Sørnes, is one of the most complex timekeeping instruments ever made. SREDNA/WIKIMEDIA COMMONS

Watch the MOON turn to BLOOD

On March 3, the Moon will change colors as it passes through Earth's shadow.

BY MICHAEL E. BAKICH

AMATEUR ASTRONOMERS, TAKE NOTE: A wonderful celestial event known as a total lunar eclipse will occur in the skies above North America during the morning hours of Monday, March 3.

Lunar eclipses happen when the Sun, Earth, and the Moon align, in that order. When this alignment is precise, Earth's shadow falls upon the Moon, obscuring it from direct sunlight. This doesn't happen every month, because the Moon's orbit is tilted to that of the Earth-Sun plane. So, most months our satellite is above or below the point (called a node) where an eclipse can happen.

This eclipse's visibility takes in a significant portion of the globe. Observers located across North and South America, Asia, and Australia, as well as the Arctic and Antarctica, can see at least some of the event — provided it's clear.

What's happening

The progression of a lunar eclipse is divided into several distinct phases, each marked by specific contact times with Earth's shadow. To complicate things just a bit, our planet's shadow has two primary components: the penumbra, which is the fainter, outer part where the Earth partially blocks the Sun's light; and the umbra, the darker, central part where Earth completely blocks direct sunlight.

The initial phase, the beginning of the penumbral eclipse, starts at 08:43:57.6 Coordinated Universal Time, which, when I convert it to Eastern Standard Time, I will call 4:43 A.M. EST. (Observers don't have to know the times more accurately than which minute each part of the eclipse will start or end.)

At this precise moment, the Moon's leading edge will contact the outer, diffuse portion of Earth's shadow. During the penumbral phase, the reduction in lunar brightness is subtle and can be challenging to see, especially during the first half-hour. But eventually you'll see the Moon gradually dim. Over the first 1 hour 6 minutes of the eclipse, you'll see Luna's face continue further into the penumbra.

A much more discernible phase, the partial eclipse, begins when the Moon's leading edge makes contact with Earth's umbra. This will happen at 5:49 A.M. EST. From

This imager placed himself at Persepolis, a UNESCO World Heritage Site, to help frame the total lunar eclipse of Dec. 10, 2011. During a span of 1 hour 50 minutes, the Moon rose from the lower left almost totally eclipsed and then brightened as it moved out of Earth's shadow. FARZAD ASHKAR

this point forward, a distinct, curved portion of the Moon's disc will appear darkened because Earth is progressively blocking more and more direct sunlight. As the Moon continues eastward through the umbra (while simultaneously setting and moving westward across the sky because of Earth's rotation), more of its surface will turn dark. This first half of the partial eclipse will last for 1 hour 14 minutes.

A colorful Moon

The total phase, the most visually striking part of the eclipse, begins at 7:03 A.M. EST. At this instant, the trailing edge of the Moon fully enters the umbra, so the whole lunar disc will now be covered by Earth's deepest shadow. Despite this, the Moon won't disappear entirely from view. Instead, it typically takes on a reddish or coppery hue, a phenomenon commonly referred to as a Blood Moon.

This reddish coloration is a result of sunlight being refracted and scattered by Earth's atmosphere. While Earth blocks direct sunlight from reaching the Moon, a small amount of light manages to bend around the edges, passing through our planet's atmosphere.

As the light moves through the air, shorter wavelengths, such as blue and green, are scattered more efficiently by atmospheric particles. (This also explains why the daytime sky appears blue.) Longer wavelengths, such as red, yellow, and orange, scatter less and thus continue through the atmosphere. This reddish light then hits the Moon, producing its characteristic reddish tint.

The exact shade of red can vary significantly from one eclipse to another. The main factor influencing coloration is the amount of dust and clouds present in Earth's atmosphere at the time of the eclipse. Volcanic eruptions, for instance, can inject large quantities of aerosols into the stratosphere. Such events lead to particularly dark or intensely red lunar eclipses.

Seeing totality?

Unfortunately, totality starts too late for those in the

For this shot of the Feb. 21, 2008, total eclipse of the Moon, the imager drove 590 miles (950 km) to Kas, Turkey, and then took a single six-second exposure. TUNÇ TEZEL

Eastern Time Zone. Even in Indianapolis, which lies at the western edge of the zone, the Moon will set on March 3 at 7:17 A.M., so it will be quite low in the west and the sky will be bright. The Central Time Zone fares better. On its western edge, say in Amarillo, Texas, moonset is also at 7:17 A.M. But that's Central Time, so totality there will start at 6:03 A.M. CST. The sky will be getting lighter (astronomical twilight begins at 5:49 A.M.), but your chances of seeing some of totality are good if your sky to the west is clear.

The point of greatest eclipse, when the Moon is closest to the center of Earth's shadow, will happen at 7:33 A.M. EST. At this time, the Moon's path intersects the umbra at its deepest point during the event. The end of totality will occur at 8:02 A.M. EST. It's at this point that the leading edge of the Moon begins to emerge from the umbra. The Moon will rapidly lose its color as direct sunlight once again falls on its visible surface, creating a sharp contrast with the remaining shadowed portion. Lunar totality will last a worthy 59 minutes. We all wish solar totalities were that long!

Because lunar eclipses happen at New Moon, you won't see many stars when our satellite is at peak brightness. As the eclipse progresses, however, more and more stars will pop into view. During totality, the Moon will lie at the northeastern tip of the constellation Sextans, which is faint even at New Moon.

North of the Moon, the wonderful constellation of Leo the Lion will emerge. It's likely that you'll be able to spot Leo's brightest star, magnitude 1.4 Regulus (Alpha [α] Leonis), all night long. As the event moves toward totality, watch the other stars of Leo gradually appear.

Part two

The second half of the partial eclipse begins at 8:02 A.M. EST and concludes at 9:17 A.M. EST. During this period, you'll see the reverse of the first partial phase, which began more than two hours prior. The bright, crescent-shaped portion of the Moon will steadily grow larger as it transitions out of the umbra and back into the penumbra. The curvature of Earth's shadow (That's right: Our planet isn't flat!) will again be evident on the shrinking dark segment of the Moon.

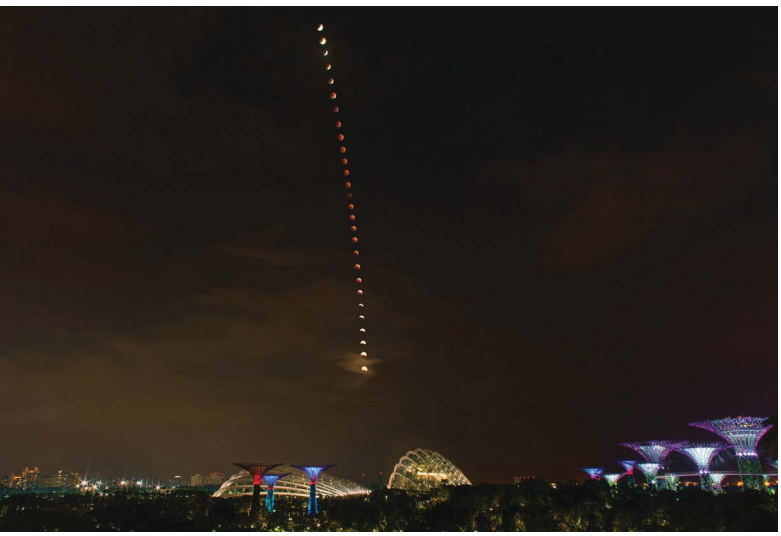
Finally, the penumbral eclipse will end as the Moon exits Earth's lighter, outer shadow. This final contact will happen at 10:23 A.M. EST. The Moon is once again fully illuminated by direct sunlight — a Full Moon in the sky. The entire event, from the initial contact with the penumbra to

LEFT TO RIGHT: This composite image combines 28 exposures of the lunar eclipse Jan. 31, 2018, taken at the Gardens by the Bay in Singapore. CHAN CHEE GUAN

The fully eclipsed Moon stands above Los Gigantes in Cibola County, New Mexico, on Jan. 31, 2018, at 6:39 A.M. DANE LAMBSON

This sequence chronicles the total lunar eclipse of Sept. 27, 2015. By all accounts, this was a dark eclipse but not one where the Moon passed through the center of Earth's shadow. Note how our satellite's bottom edge looks brighter in these images. PHILIPPE MOUSSETTE

This wide-angle composite of the total lunar eclipse of Jan. 20, 2019, consists of 68 frames spaced three minutes apart. The photographer later added the foreground image. LAKSHMINARAYANAN GOWRISHANKAR



This scene shows the positions of the eclipsed Moon on Jan. 31, 2018, as it descends the western sky over San Francisco. The imager stacked 17 exposures taken from the USS *Hornet* Museum in Alameda, California. WESLEY CHANG

the final exit from it, spans 5 hours 39 minutes.

Observe this eclipse

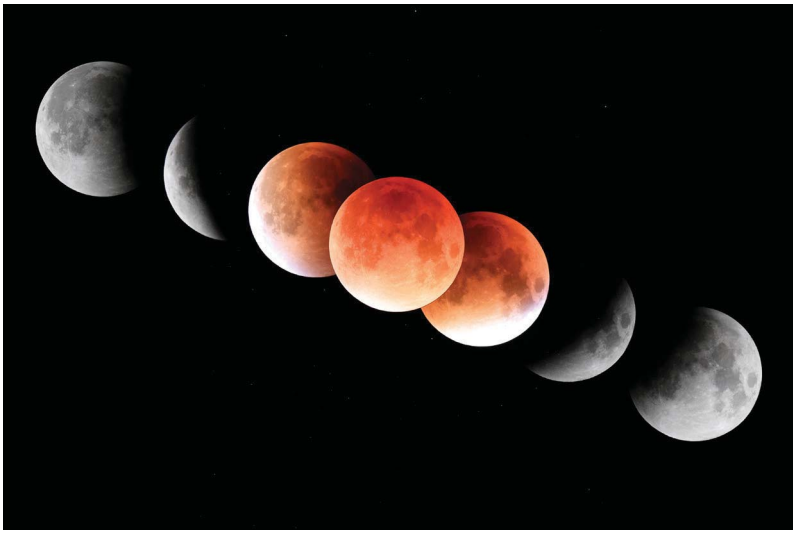
Here's the good news: You don't need any equipment or eye protection to view a lunar eclipse. The Full Moon is always easy to see and the light striking your eyes is just reflected, not direct, sunlight. That said, most observers agree that the most pleasing views of the Moon, especially during totality, are through binoculars. Models marked 7x50 or 10x50 will serve well. Higher-power models accentuate the involuntary motions of your hands and arms — though if you mount them on a tripod, they'll work fine.

All eclipses demonstrate orbital mechanics and the makeup of shadows in the solar system. The March 3 total lunar eclipse gives us just such an opportunity to witness Earth's shadow cast upon its one natural satellite during an exact lineup of three celestial bodies.

My advice: Go out and experience this event, even if you can only see part of it. The next total lunar eclipse won't happen until New Year's Eve 2028, and it's not a favorable one for the U.S. A slightly better one, mainly for the eastern U.S., will happen June 25, 2029.

More than three years is a long time to wait. So, set up a lawn chair, make a warm drink, grab a blanket, and experience what I like to call sublime celestial geometry. Good luck!

Michael E. Bakich *is an associate editor of* Astronomy *who painfully admits to seeing his first total lunar eclipse in the 1950s.*



MAGNIFICENT NGC CLUSTERS IN THE WINTER SKY

Whether you observe them visually or photograph them, these star cities will delight.

STORY AND IMAGES BY ROBERT REEVES

THE WINTER SKY is dominated by sparkling bright stars dotting the Milky Way. Among the myriad star clusters, many that stand out in the eyepiece steal visual observers' hearts. The popular Messier catalog gets the lion's share of attention along the starry highway in the sky, but there is a bounty of amazing objects in the *New General Catalogue* (NGC) that rival their Messier cousins and deserve our attention.

Like the summer sky, the winter Milky Way is peppered with star clusters listed in the NGC. To the novice amateur astronomer, these objects are cloaked in mystery — faraway places whispered in numeric code among elite observers as they huddle and seemingly merge with their eyepieces to pierce the darkness. Every large star party has one such gathering, its members communicating among themselves with obscure four-digit numbers that sound like secret agent code-talk.

And while the warm summer skies are inviting, often mosquitoes and humidity take their toll on our

1 The Double Cluster in Perseus is visible to the naked eye under moderately dark skies. The two clusters are NGC 869 (magnitude 5.3) on the west and NGC 884 (magnitude 6.1) on the east. Each cluster spans half a degree of sky and contains 200 and 150 stars, respectively. Their combined glow makes them a spectacle in binoculars. At magnitude 3.7, NGC 869 is 0.1 magnitude brighter than NGC 884, which lies about 150 light-years beyond its companion. Both are about 14 million years old.

2 Open cluster NGC 1245 is a rich concentration of 200 faint stars in Perseus that render the cluster as a subtle glow in a low-power telescope. Its diameter is 10′ and its overall magnitude is 8.4. The cluster lies three degrees southwest of Mirfak and shares the same binocular field as the broad Alpha Persei star cluster surrounding Mirfak.

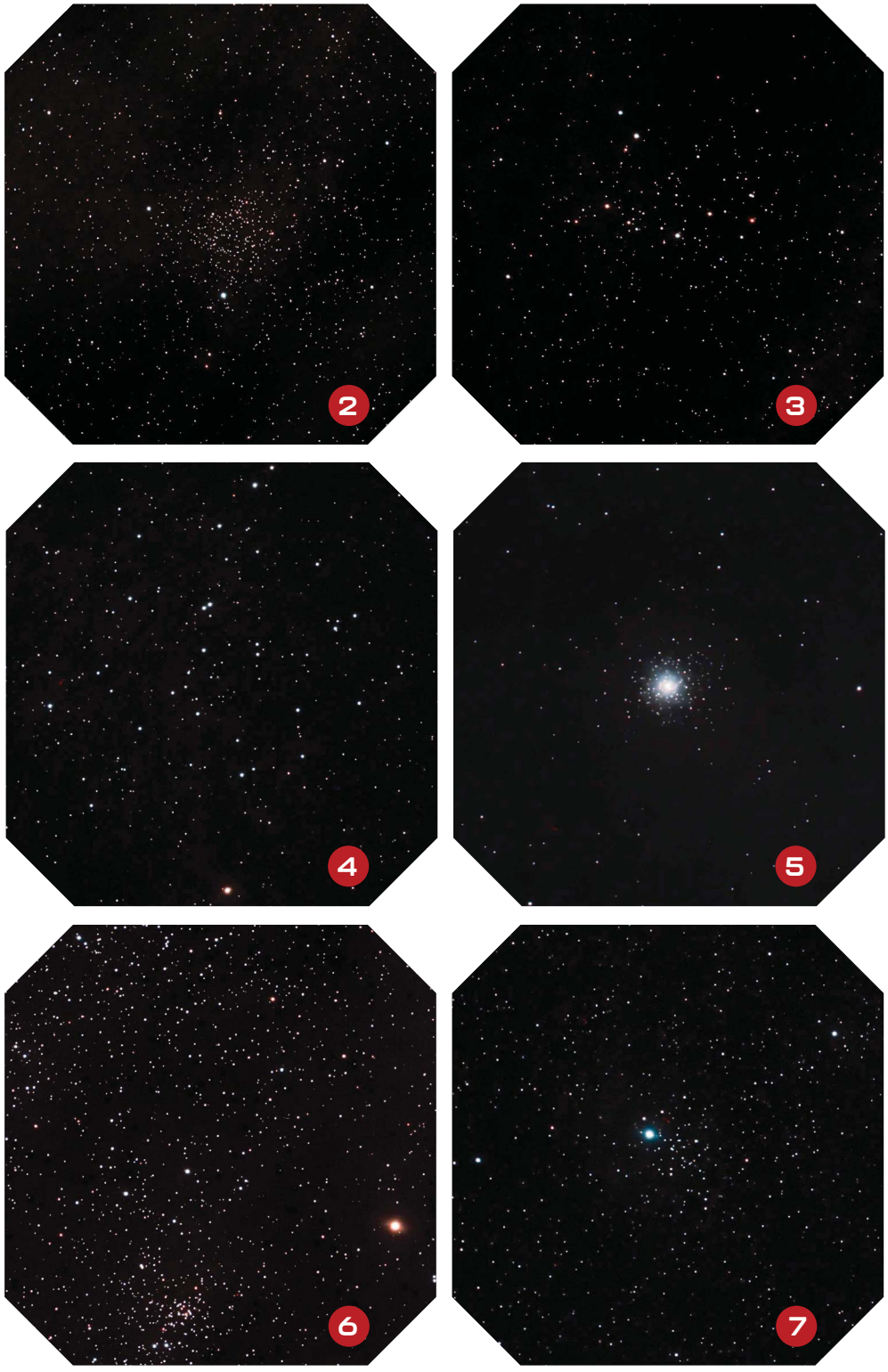
3 NGC 1342 is a loose collection of 40 stars in Perseus with its brighter members irregularly draped across the background of fainter cluster members. A noticeably reddish star lies on the eastern side of the cluster. It spans 14′ and glows at a worthy magnitude 6.7.

4 Lying between the horns of Taurus and spanning three-quarters of a degree, NGC 1647 defines the term "loose star cluster." At magnitude 6.3, this aggregate of 50 stars is an easy binocular target, but it's so spread out that moderate telescopic magnification looks right through the middle of the cluster.

5 Estimated to be some 9.2 billion years old, NGC 1851 is a bright (magnitude 7.1) globular cluster that rivals many similar objects in the Messier catalog. Located about 40,000 light-years away, NGC 1851 displays features — including a tidal tail — that suggest it may be the remains of a dwarf galaxy that was stripped of its shell of stars, leaving a large globular cluster. Its diameter is 12′.

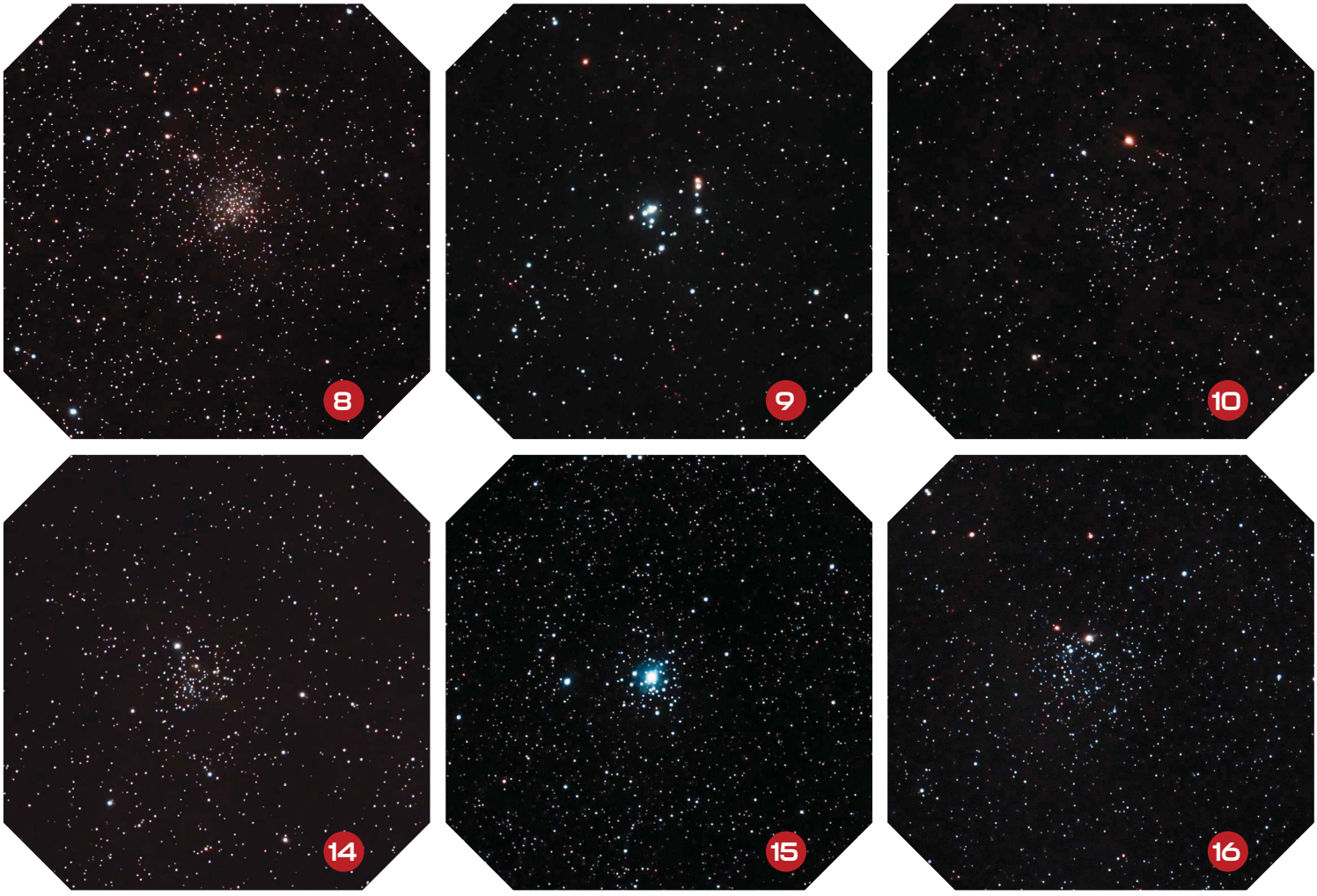
6 NGC 1907 is small (6′ wide), but its location one-half degree south of the open cluster M38 makes this magnitude 8.2 grouping of 30 stars an often accidentally observed object. A curiosity is the cone-shaped aggregation of stars that appears to link NGC 1907 to M38. However, there is a 1,000 light-year difference in the distance to each cluster and the alignment we see is purely by chance.

7 While binocular highlights like M36, M37, and M38 spread like a belt across Auriga, unsung telescopic targets like the tight open cluster NGC 2126 also beg for our attention. The 6th-magnitude foreground star SAO 40801 looks like an oncoming headlight overlaying this grouping of 40 stars. NGC 2126 has a diameter of 6′ and glows softly at magnitude 10.2.



observing comfort. The cool, crisp winter skies offer a view free from summer's haze, and it's easier to bundle up against Jack Frost's chilly presence than it is to keep cool on a muggy night. The cosmic sweep through Perseus, Auriga, Gemini, Orion, Canis Major, and Puppis richly reward those who brave the winter elements. But appreciating an eyepiece view of the celestial jewel boxes within the NGC is much like appreciating art, subjective and dependent on the eye of the observer. Indeed, the same star cluster that appeals when rising in the east may present an unappealing pattern when seen "upside-down" in the west.

The novice often sees the NGC catalog as a collection of ultra-faint galaxies. But there are also hundreds of star clusters well worth our viewing effort. Indeed, some NGC clusters out-marvel their Messier counterparts and gain special reverence among experienced observers. I view the NGC catalog as a ticket to



travel the universe, even through a modest telescope.

Part two

In the July 2025 issue of *Astronomy*, I led a tour of 14 star clusters visible in the Northern Hemisphere's summer sky. (Scan the QR code at bottom right to read it.) This story is the follow-up. The 17 clusters I list here are best seen in the winter sky north of the equator. Most can be observed through a 4-inch telescope. The faintest, NGC 2192 at magnitude 10.9, will require an 8-inch instrument.

As before, I took all the images through my equatorially-mounted Celestron Origin telescope in a mini-observatory in my backyard, from the middle of San Antonio, Texas. Under such a light-polluted sky, the images this scope captures are nothing less than amazing. My only modification is to install Celestron's nebula filter, which the company made specifically for this telescope. I capture twenty 30-second exposures at ISO 200, and the Origin's AI then stacks and processes the images.

It is humbling to realize that all the sparkling snowflakelike star clusters are in our galactic neighborhood. Thousands of similar clusters are spread across the opposite side of the Milky Way, either obscured by the mass of the galaxy or beyond our telescopic reach. The Milky Way is vast, and observing star clusters brings scale and depth to the seemingly infinite reaches of space. As you enjoy the appealing winter NGC star clusters — whether you choose to look at them or image them — take some time to think about and fathom the depths of our galaxy.

Robert Reeves *is a longtime amateur astronomer and astroimager who loves pushing new (and old) equipment to its absolute limits.*

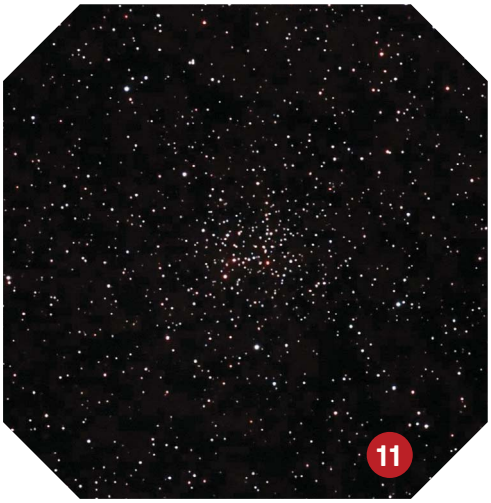
8 NGC 2158 is a compact (5′ diameter), sparkling open cluster lying only half a degree from the more popular M35 in the right foot of Gemini. Though smaller than M35, this rich, magnitude 8.6 cluster boasts nearly 1,000 stars. Although most of NGC 2158's stars are too faint to be seen individually, they combine to provide a pleasing glow.

9 When viewed with modest telescopic magnification and oriented north up, NGC 2169 in Orion splits into two groups of stars, the eastern side forming the number 3 while the western side forms a 7, so many amateur astronomers call it the 37 Cluster. You'll find it a degree west of Xi (ξ) Orionis, Orion's club-wielding right hand. Spanning 6′ and glowing at magnitude 5.9, NGC 2169 is easy to locate in binoculars.

10 Although it glows softly at magnitude 10.9, NGC 2192 continues the theme that Auriga is populated with magnificent star clusters. Composed of 40 stars, the 5′-wide cluster is punctuated by the endearing reddish 7th-magnitude star SAO 58894 that beckons our telescopic attention and points to NGC 2192.

11 Open cluster NGC 2194 is located 1.7° southeast of NGC 2169. Indeed, this cluster of about 80 stars shares a binocular field of view with Orion's 37 Cluster. A half-dozen reddish-gold stars overlay the cluster's predominantly white star pattern. It has a diameter of 10′ and glows at magnitude 8.5.

12 Lying 13,400 light-years distant, open cluster NGC 2204 presents a pleasing star pattern of 80 stars that is competitive with some Messier objects. It glows at magnitude 8.6 and spans 12′. Adding to the cluster's appeal is the 6th-magnitude star SAO 151274, which lies 12′ north of the cluster's center.



13 A roughly ladder-shaped pattern of bright stars overlays the 100 stars comprising open cluster NGC 2244, which lies at the heart of the Rosette Nebula. Several O-class stars, such as the ones at the upper left and lower right of the ladder asterism, are among the largest and most luminous stars in the Milky Way. NGC 2244 has a diameter of 23′ and an easy naked-eye magnitude of 4.8.

14 Lying 12,000 light-years from the Sun and opposite the galactic center, the 50 stars of NGC 2266 in Gemini are easily resolved in a modest telescope, despite the cluster's small size (6′) and relatively low brightness (magnitude 9.5). The brightest star at the southern side of the cluster is magnitude 8.9 SAO 78670.

15 At 6′ in diameter, NGC 2362 would normally be little different from hundreds of other distant NGC open clusters. However, this bright (magnitude 3.8) collection of 60 stars in Canis Major is highlighted by the centrally placed magnitude 4.4 foreground star SAO 173446.

16 Puppis is dusted with dozens of star clusters, which make the constellation a large-binocular paradise. Open cluster NGC 2439, a tight collection of 80 stars, distinguishes itself among its peers by cleanly hovering before the sparser star background while being punctuated by two bright foreground stars. It spans 10′ and glows at magnitude 6.9.

17 A declination of –38° makes NGC 2477 a challenge for midlatitude observers in the Northern Hemisphere. This cluster of 300 stars spans 27′, nearly the visible width of the Full Moon. And despite its unsavory nickname of the Termite Hole Cluster, its magnitude 5.8 brightness is a stunning apparition in a low-power eyepiece.

Scan this code to read the author's previous story online.

The author keeps his Celestron Origin telescope in a small enclosure in his backyard.

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The dance of the Moon

Image by Josh Dury

MORE THAN 4,000 YEARS after the stones of Stonehenge were erected on what today is Salisbury Plain in the U.K., astronomers and archaeologists are still investigating its connections to the sky above. In particular, while Stonehenge is famous for its alignments with the Sun, some scientists argue the monument is also a temple to the Moon.

Astrophotographer Josh Dury captured this concept visually in what he calls the "dance of the Moon," a sequence showing Luna arcing dramatically over Stonehenge's megaliths. The composite was taken over a single night during the 2024/5 major lunar standstill — an alignment of the Earth and Moon that occurs only every 18.6 years.

This alignment is related to the Earth's tilted rotational axis and the smaller tilt in the Moon's own orbit. Earth's tilt is responsible for the seasons, causing the Sun and Moon to migrate higher and lower in the sky. But because the Moon's orbit is also tilted an additional 5.14° with respect to the ecliptic, the Moon performs an additional, subtler migration. Every 18.6 years, as its orbit precesses, those tilts align, causing the Moon to rise and set at its northernmost and southernmost extremes, reaching declinations of around 28.7° north or south of the celestial equator. This produced unusually low arcs of the Moon over Stonehenge.

The recent major standstill caught the attention of researchers, who took the opportunity to put Stonehenge's proposed lunar alignments to the test. "Stonehenge's architectural connection to the Sun is well known, but its link with the Moon is less well understood," said Clive Ruggles, an archaeoastronomer at Leicester University, in a 2024 news release announcing this campaign.

In particular, a set of four stones — called the Station Stones — are set in a rectangle outside the circle of megaliths. The short axis of this rectangle points toward the midsummer sunrise and the midwinter sunset — the well-known solstice alignments. But researchers

have also noted that the long axis of the Station Stones points toward the southernmost moonrise at a major lunar standstill. "Researchers have debated for years whether this was deliberate, and — if so — how this was achieved and what might have been its purpose," said Ruggles.

To capture this intersection of folklore, history, and modern science, Dury chose Aug. 4, 2025, for the Moon's low declination on that date of around –28°. This meant the Moon would reach no higher than 11 degrees at Stonehenge's latitude of 51° North.

Dury had previously photographed Stonehenge on behalf of English Heritage, the charity that manages the monument grounds, and obtained permission to set up near the location of the northernmost Station Stone. To plan the shot, Dury used The Photographer's Ephemeris, an online visualization tool and mobile app.

Because the Moon was a waxing gibbous, Dury shot the first half of the sequence in fading twilight, requiring careful exposure management. Later, at night, Dury dialed the shutter speed back down to ensure the Moon was not overexposed and its disk remained defined.

"It was quite a hazy sky," said Dury, and as a result, "the light was a lot more minuscule and not as refined. And so it created quite a stunning, really, visual effect above the monument."

Dury is a full-time astrophotographer and the author of *52 Assignments: Night Photography* (Ammonite Press, 2025), which contains a year's worth of weekly lessons and challenges. He advises nightscape photographers to seek a greater connection with their subject. "Rather than being tethered to aspects like social media influencer images and, in some instances, repetitive images, look to create unique, striking images from your own perspective of life," he said.

In conceiving this shot, Dury, who hails from nearby Somerset and first visited Stonehenge a decade ago as a university student, drew on his technical skills and creativity. But he was also drawn to the site's history and the reasons its builders constructed it — "what the Moon must have meant to those people and their greater connection to the sky above us."

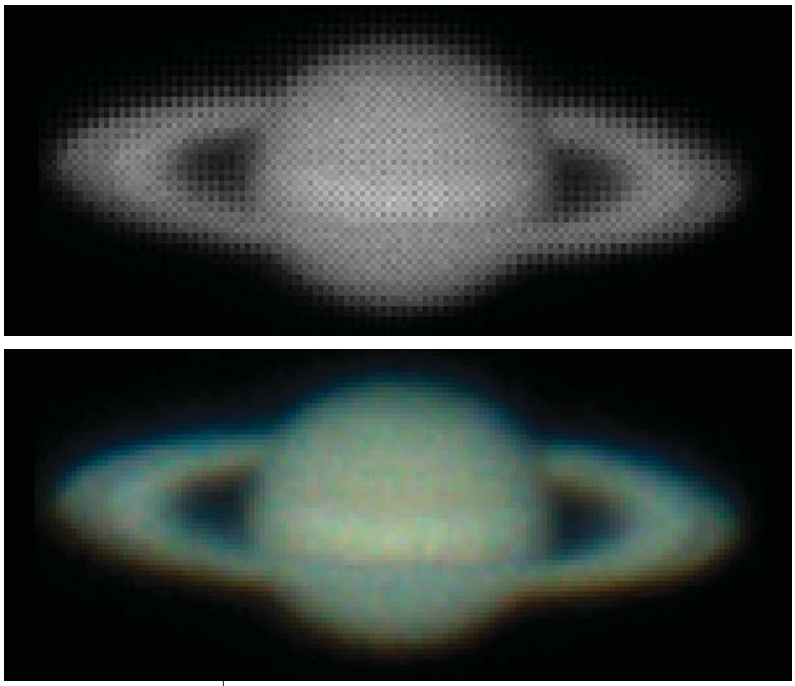
Such considerations give us "a cultural lens into the past," said Dury. "It also makes you think more about what you are photographing, your own connection to the experience."

Dury notes that the original priests or observers at Stonehenge lacked the benefits of modern medicine, meaning a major lunar standstill could well have been a once-in-a-lifetime event. Even today, the passage of nearly two decades between major standstills instilled a profound sense of perspective — and an urgency to get the shot. "I'm 27 now; the next time it happens, I will be 43," he said. "You almost have to bite the bullet with these things to witness them firsthand." **—Mark Zastrow**

Aug. 4, 2025 • Wiltshire, U.K. • Sony a7S II • Sigma 20mm f/1.4 DG DN
Exposure settings: Various, adjusted over the course of the sequence
© English Heritage/Josh Dury

Camera face-off

One-shot color versus monochrome, which is best for you?



The image on the top is a raw OSC single frame of Saturn. The checkerboard pattern of the Bayer matrix is visible. The image on the bottom is the same frame after it was debayered.
MOLLY WAKELING (2)

BY MOLLY WAKELING
Molly is an avid astrophotographer active in STEM outreach. She has a Ph.D. in nuclear engineering.

When a budding astroimager decides they're ready to move past their DSLR and buy a dedicated astro camera, a hard question arises: Should they choose a one-shot color or monochrome camera? It's a difficult decision because both have advantages and disadvantages.

One-shot color cameras (OSC) capture all three color bands (red, green, and blue) in one image, just like a DSLR or smartphone. They have a grid of tiny color filters arranged in 2x2 squares on top of the sensor. A common type of array is the Bayer matrix, named for Kodak scientist Bryce Bayer, its inventor. In each group of four pixels, one is red, two are green, and one is blue. (Green is doubled because our eyes are most sensitive to the green part of the spectrum, the peak of the Sun's light emission.)

In the raw version of OSC images, each pixel records the intensity of the red, green, or blue light as a number, and the image will appear monochrome with a checkered pattern. To make a color image, the raw image is "debayered," a process that interpolates the surrounding similar pixels to estimate the specific color in each pixel. DSLRs and phone cameras do this automatically, but astrophotographers need to use image-processing software to debayer their images after calibrating them, before they register or align them. There are several different algorithms for accomplishing this.

It's a difficult decision because both have advantages and disadvantages.

Monochrome cameras, on the other hand, do not have a Bayer matrix; each pixel records the intensity of the light that falls on it. Red, green, and blue filters are placed in front of the camera to capture the intensity of each color, and then those are combined into a single RGB image at a later point during processing.

So which kind of camera should you get? There are several factors to consider. Here's my list of the winners for different categories.

True resolution: Mono

This is the winner because there is no interpolation to determine the color of a pixel.

Light transmission: Mono

The tiny color filters of the Bayer matrix can have lower light transmission efficiency than filters of monochrome cameras. It's a little more complicated than this, but users of both kinds of cameras will notice a difference, particularly in narrowband imaging.

Total frames needed: OSC

Since OSC cameras capture all bands of optical light in one image, fewer total frames are needed to make a complete color image than with monochrome cameras. This is advantageous when you have little time under a good sky, such as at a star party.

Ease of preprocessing: OSC

In this case, you only have to calibrate, register, and stack one set of images rather than three to make an RGB image. Just don't forget to debayer!

Processing flexibility: Mono

Mono offers more ways to combine the different color channels, particularly if you're doing narrowband imaging. You can also take luminance frames, which capture the intensity of all the optical wavelengths of light at once, making a higher signal-to-noise ratio image that can showcase more detail.

Cost: OSC

Not only are OSC cameras cheaper than mono (due to economy of scale with all the DSLRs out there), but when you have a mono camera, you also need color filters and a filter wheel.

So who wins the battle? It all depends on your needs. If you have a little more money and more clear nights, monochrome cameras can produce higher-quality images but also require more processing. OSC cameras, on the other hand, are cheaper and require fewer total frames to make a complete image, maximizing time under good skies. I like to have both!

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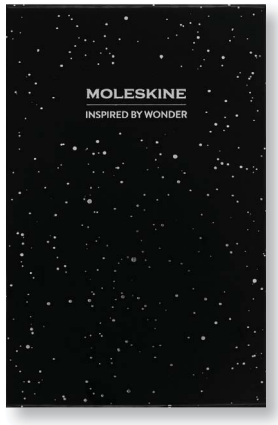

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MARKETPLACE

Timelapse photography of star trails is a visual reminder of Earth's rotation. We can't feel the movement because the velocity is consistent, but we would immediately feel the catastrophic effects if that spin were to stop. ALAN DYER

If Earth stands still

Q WHAT HAPPENS IF EARTH STOPS ROTATING?

Etan Meyer
Boca Raton, FL

A I will assume you're referring to what would happen if Earth stopped rotating all at once, without any gradual reduction in velocity. In that event, most things on Earth would be almost immediately destroyed.

To illustrate, let's say you're riding in a car. If the car is traveling at 70 mph (112.7 km/h), your body will also be traveling at 70 mph. If the car suddenly stops, your body initially continues to move at 70 mph — which is why a seatbelt is necessary to prevent you from moving rapidly toward the windshield. We don't feel motion when we travel at a constant velocity. We do feel motion when our vessel experiences a sharp acceleration or deceleration.

Now, most of Earth is moving much more quickly than a car. A point along the equator moves at approximately 1,037 mph (1,668 km/h). This tangential velocity decreases with increasing distance from the equator; for instance, Earth's speed in New York City is about 794 mph (1,277.8 km/h), and at the poles, it is reduced to zero. (You can figure out this speed V in mph at any latitude with the formula $V = 1{,}036\cos(latitude)$.) If Earth stopped spinning in an instant, all the water, air, and structures on Earth would still be moving at speeds corresponding to their latitudes.

So on the equator, you'd experience wind speeds in excess of 1,000 mph, a velocity nearly five times greater in speed (and 25 times greater in force) than the strongest wind speed ever recorded on Earth's surface to date. Anybody who's ventured outside to experience a 75-mph wind gust can begin to appreciate the power of 1,000-mph winds. Almost all structures would collapse at once, and everyone and everything not firmly anchored to the ground would be violently displaced. Even the ground itself would buckle, split, and tear in response to a sudden stop.

Not to mention the oceans: Remember that the water in the oceans will also be moving along Earth's surface at a speed corresponding to its latitude. If Earth were to stop turning suddenly, that water would continue to move at a rapid velocity, inundating coastal and possibly even inner regions with a deluge of displaced ocean water. The ocean surface might yield to our touch, but anyone who has waded in a swift current will know water's immense power.

We would experience other effects as well, such as the distortion of Earth's shape. We often describe our planet as spherical, but Earth is actually an oblate spheroid (the distance across the equator is slightly greater than the distance separating the poles). This oblateness results from the centrifugal force of the planet's rotation. Without that centrifugal force, the planet would quickly become more spherical, causing the ocean waters to migrate rapidly toward the poles.

Oceans drowning large swaths of the continents; winds far more intense than humans could withstand; Earth's surface cracking violently open; volcanoes erupting worldwide and spewing megatons of ash, fire, and debris into the atmosphere — in short, the end of the world could be achieved merely by stopping its spin.

Incidentally, after the introduction of atomic clocks, scientists became aware that Earth's rotation rate fluctuated, both speeding up and slowing down. Over time, the general trend was toward diminishing — but the decrease in speed was very gradual, only fractions of milliseconds per year. Beyond the occasional addition of "leap seconds" to compensate, ramifications over the short term were negligible. (Between 1972 and 2020,

28 leap seconds were added to atomic time.) However, recent measurements have shown a trend toward an increased rate of rotation, suggesting a leap second may actually need to be subtracted in 2029. Tidal forces, seismic events, climate change, and many other factors can affect Earth's rotation rate, so even though fluctuations will continue, you can rest assured that Earth will never actually stop rotating.

Edward Herrick-Gleason
Astronomy Educator, St. John's, Newfoundland and Labrador

IN SHORT, THE END OF THE WORLD COULD BE ACHIEVED MERELY BY STOPPING ITS SPIN.

Q | PRIOR TO COMPUTER TECHNOLOGY, HOW DID ASTRONOMERS SO PRECISELY PREDICT SOLAR ECLIPSES?

Kurt Petersen
Sheboygan Falls, WI

A | What a wonderful question! The simple answer is that they relied on centuries of previous observations. Remember, even computers have to be programmed with the right data to produce future times of eclipses.

The more involved answer is that, around the seventh century B.C.E., the Chaldeans, an ancient Mesopotamian society, began using a specific time period to predict lunar eclipses. It's called the saros, and it also works for solar eclipses. Simply put, the saros is a time period after which nearly identical eclipses repeat. The Greeks living in the second century B.C.E. also knew of the saros.

The saros cycle equals 6,585.3211 days. That's how long it takes for four different cycles of the Moon to once again coincide. Those periods are: the Moon's orbital period; its phase or synodic period; its nodal or draconitic period; and its anomalistic period, which is the time from one lunar perigee to the next. The number of days in a saros cycle works out to 18 years plus a bit more than 11 days. In 11 days, Earth travels only 3 percent of its orbit and the Sun's declination (its height in the sky) varies by no more than 4°. So, if you know the date of one eclipse, you can predict that a nearly identical eclipse will occur one saros later, with the midday Sun of each at nearly the same altitude. That second eclipse, however, will occur at a much different place on Earth. That's because the saros isn't a round number of days. The extra — 0.3211 day — equals 7 hours 42 minutes 23 seconds, so that next similar eclipse will happen this much later. During that time, Earth rotates 115.6°, so you couldn't see the next eclipse from the same spot. (OK, maybe the partial phase of each, but not totality.)

But in three saros cycles, Earth would shift by 346.8°, only 13.2° less than a full rotation. So, not only will that eclipse be similar to one 54 years and 33 days before, it will occur within an hour of the same time of day. Ancient skywatchers may not have been able to duplicate the subsecond accuracy of today's eclipse predictions, but, by keeping careful records and using the saros, they could get pretty close.

Michael Bakich
Associate Editor

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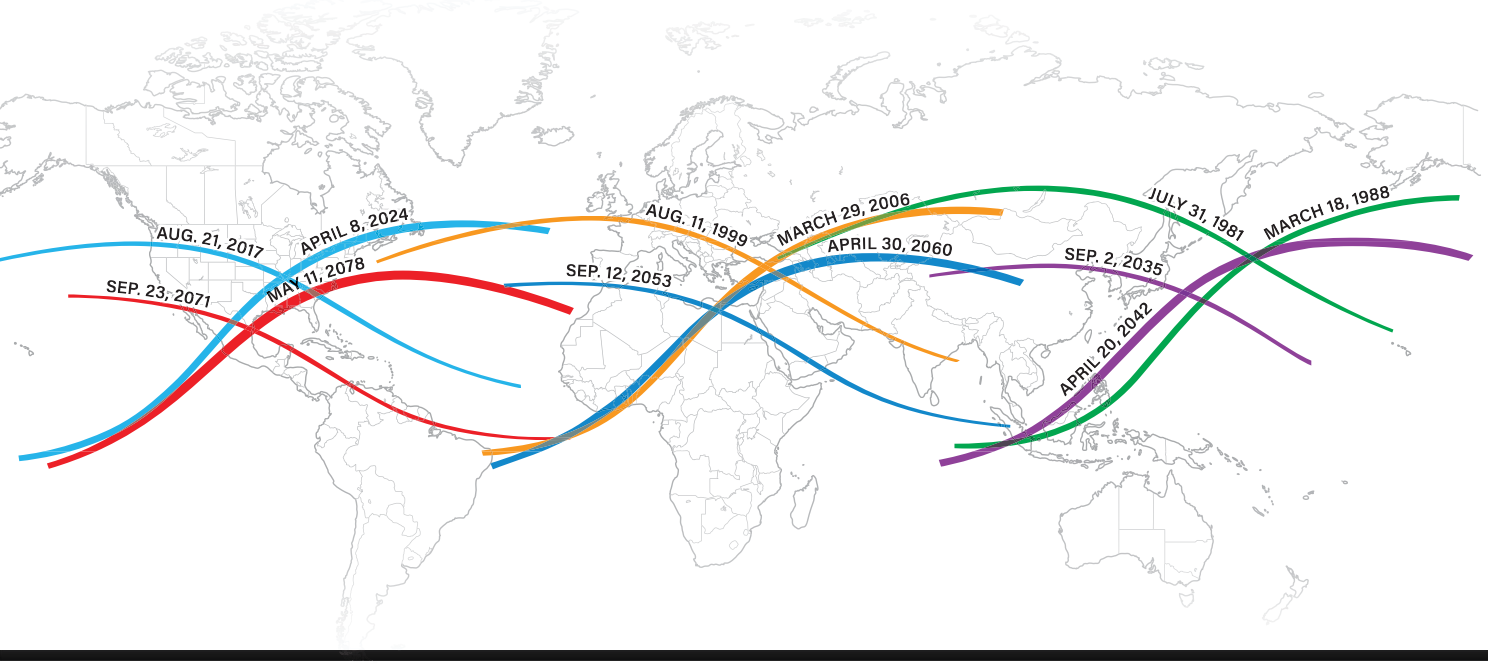


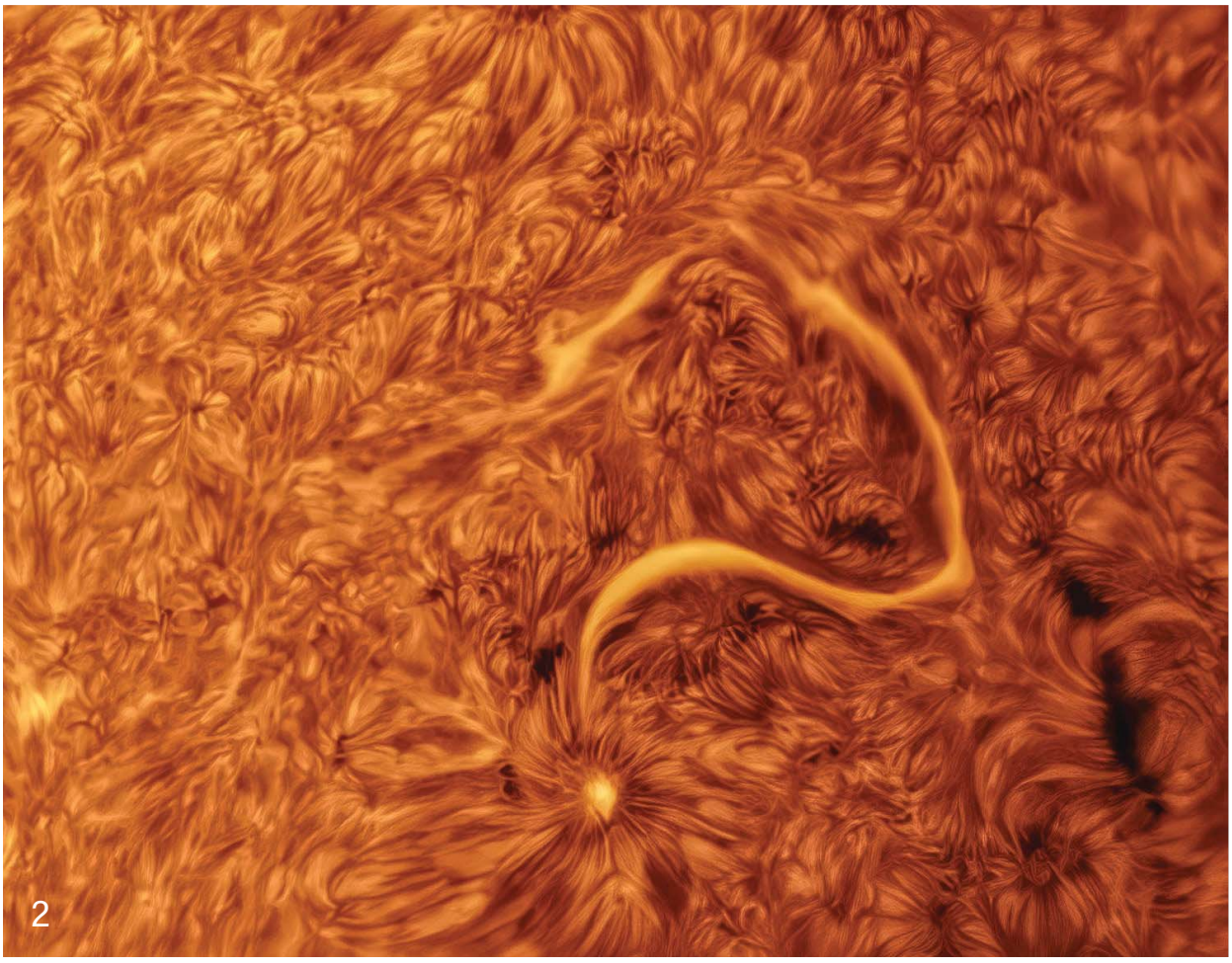
The basic geometry of eclipse paths across Earth repeats every 18 years and 11 days — one saros cycle. *ASTRONOMY:* ROEN KELLY

1

1. CATCHING LEMMON'S TAIL
Comet Lemmon (C/2025 A6) outperformed expectations as it sped through the inner solar system this fall, visible to the naked eye and showing rapidly changing detail in photographs, including this billowing episode on Halloween evening. The imager used an 11-inch Celestron RASA scope, taking four 60-second subframes.
• ***Allen Hwang***

2. A FILAMENTARY QUESTION
A solar filament winds its way across the surface of our star, with a sunspot at the bottom appearing to form a question mark. The imager captured this Hα shot with a 6-inch scope and a double-stacked 0.3-angstrom filter and etalon. • ***Mark Johnston***

3. COSMIC LATTE
Coffee is served in the foreground of this carefully planned self-portrait featuring both the winter and summer arches of the Milky Way. Panoramas of each were taken on successive nights at the end of March in Val-d'Oronaye, France, with a Sony mirrorless camera and 24mm f/1.8 lens with six-second exposures at ISO 6400.
• ***Pablo Javier Lucero***



2

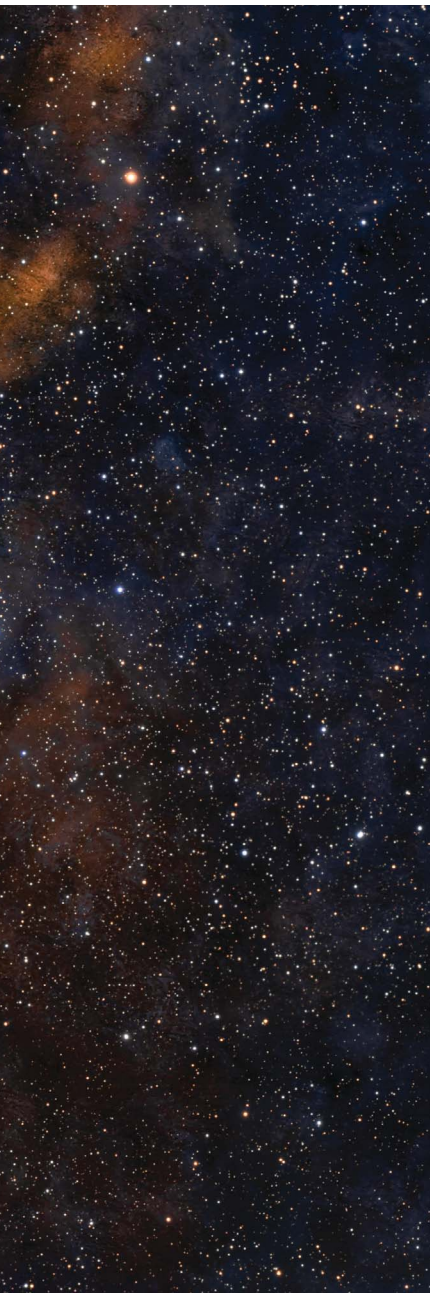
3

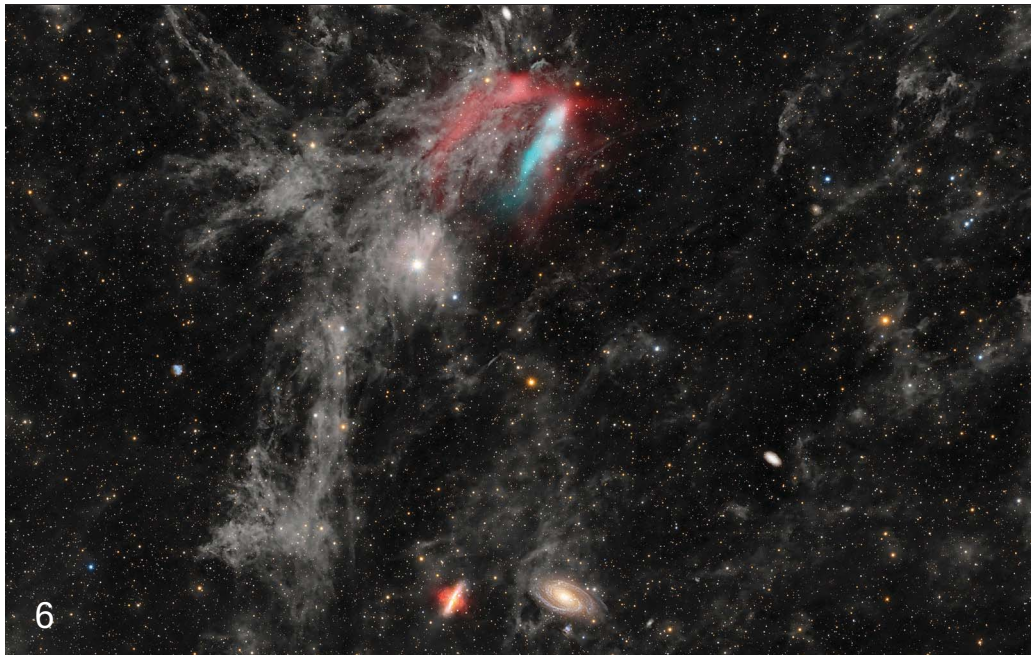
SEND YOUR IMAGES TO: readergallery@astronomy.com.
Please include the date and location of the image, your mailing address, and complete photo data: telescope, camera, filters, and exposures.

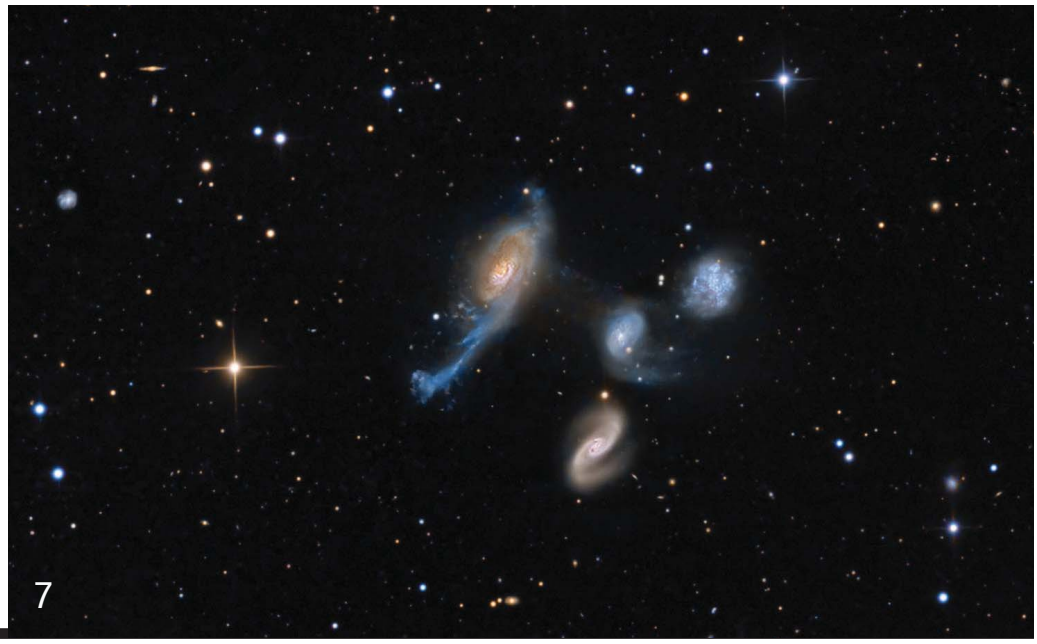
4. A TRIFLE FAMILIAR
Sharpless 2–124 is a faint emission nebula located around 15,000 light-years away in Cygnus. This image reveals intricate filaments of dust crossing the bright central region, reminiscent of the Trifid Nebula (M20). The imager took 14.2 hours of SHO and LRGB data with a 2.8-inch f/5.6 astrograph. ***• Patrick A. Cosgrove***

5. A REALLY FULL MOON
A Full Moon rises behind the cityscape of Noto, Sicily, Italy, on the evening of Oct. 8, 2025. The imager used a Canon mirrorless camera and a 500mm zoom lens with a 2x teleconverter for a focal length of 1,000mm at f/14. The exposure was 0.8 second at ISO 6400. ***• Gianni Tumino***

6. THE DUSTY VULCAN
The region around the galaxies M81 and M82 (bottom center) contains copious galactic cirrus — foreground dust that lies in our own galaxy, illuminated not by an individual star but the Milky Way's faint ambient glow. Among these wispy clouds lies the Vulcan Nebula (WPS 46), perched above the galaxies in this deep exposure of 193⅓ hours. The imagers used a 135mm f/2 lens, monochrome and one-shot color cameras, and LRGB plus Hα, OIII, and dual-band SII/OIII filters. ***• Hunter Outten/Spencer Stecz/Kaleb Jordan***







7. A DISSIMILAR BUNCH
The galaxies of Robert's Quartet in the southern constellation Phoenix feature very different morphologies. The largest member is NGC 92 (left), whose distorted spiral arm is evidence of a previous interaction — as is the faint broad bridge of stars connecting it to NGC 88 (center). Spiral NGC 89 (bottom) and irregular NGC 87 (right) round out the group. The imager took four hours of LRGB exposure with a 24-inch scope. ▪ ***Kfir Simon***

A RELUCTANT STAR

Lurking in the southwestern corner of Aquarius the Water-bearer, globular cluster M72 doesn't stand out. At magnitude 9.4, it ranks among the dimmest globulars Charles Messier included in his celebrated catalog. But M72 also lies farther away than most Messier clusters. Its 100,000 stars shine across 55,000 light-years of intragalactic space. M72 appears to be about 9.5 billion years old, younger than most of our galaxy's globulars. Astronomers suspect the Milky Way may have captured it when a smaller galaxy passed by long ago. The cluster's central regions harbor many blue stragglers — hotter-than-typical globular stars that form either through mergers or the transfer of mass between binary companions. Hubble scientists created this image from observations at ultraviolet, optical, and infrared wavelengths. ESA/HUBBLE & NASA, A. SARAJEDINI, G. PIOTTO, M. LIBRALATO

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April 2026
Mercury at its best

April evenings provide views of the two brightest planets, though only one stands out. **Jupiter** gleams at magnitude –2.1 and dominates the northern sky as twilight fades to darkness. It lies in Gemini the Twins, to the left and a bit above that constellation's brightest star, magnitude 1.2 Pollux.

The giant planet sits well north of the celestial equator, so it hangs fairly low in our Southern Hemisphere sky. Still, it's worth viewing through a telescope. Jupiter spans 37" at midmonth and should show a wealth of atmospheric detail during moments of good seeing. And the gas giant's four bright moons always put on a good show.

Although **Venus** shines at magnitude –3.9, some five times brighter than Jupiter, it's not as prominent because it sets during twilight. Look for it low in the northwest about 45 minutes after sunset, particularly late in the month when it's a little farther from the horizon. The inner planet doesn't climb high because the ecliptic — the apparent path of the Sun across the sky that the planets follow closely — makes a shallow angle to the western horizon on April evenings.

Venus lies far from Earth and thus looks small through a telescope. On April 30, its disk measures 12" across and appears nearly 90 percent lit.

While the predawn sky lacks the bright planets of evening, it makes up for it with several close encounters. Mercury, Mars, and Saturn gather during April's second half, especially on the 19th and 20th.

The star of this trio has to be **Mercury**, which puts on its best morning show of the year. The inner planet reaches greatest elongation April 3, when it lies 28° west of the Sun and stands 15° high an hour before sunrise. Take a few moments to view magnitude 0.3 Mercury with your telescope. On the 3rd, the planet's disk spans 8" and appears half-lit.

Mars starts the month about 10° below Mercury. The ruddy planet shouldn't be hard to spot, although its magnitude 1.2 glow is less than half as bright as Mercury's. The two planets reach conjunction April 20, when 1.8° separate them. A telescope reveals no detail on Mars' 4"-diameter disk.

Saturn completes our planetary trio. The ringed world has just started to edge away from the Sun and climbs higher in the morning twilight with each passing day. On the 20th, magnitude 0.9 Saturn passes 0.5° north of Mercury and 1.3° south of Mars. Unfortunately, the ringed planet lies too low to show much detail through a telescope.

A waxing gibbous Moon occults the 1st-magnitude star Regulus in Leo on April 26. The best viewing locations in the Southern Hemisphere are in eastern South America. From Vitoria, Brazil, the star disappears behind the Moon's dark limb at 0h46m UT and reappears at the bright limb at 3h35m UT.

The starry sky

Without a doubt, one of the sky's most striking asterisms is the three stars that form Orion's Belt. Because Orion straddles the celestial equator, and the belt represents the Hunter's midsection, many people think the trio marks the celestial equator. Although the three stars come close, all of them lie in the southern celestial hemisphere. The belt is well-placed in the western evening sky throughout April.

Of the three belt stars — Mintaka (Delta [δ] Orionis), Alnilam (Epsilon [ε] Ori), and Alnitak (Zeta [ζ] Ori) — Mintaka lies closest to the celestial equator, standing just 18' south of the line that separates the two hemispheres. Alnilam and Alnitak reside at declinations of –1°12' and –1°57', respectively. (All positions are in epoch 2000.0 celestial coordinates.) Mintaka glows at magnitude 2.2 while the other two appear slightly brighter, shining at magnitude 1.7.

I have enjoyed viewing these stars since childhood. In my early days of stargazing, I naively thought they were bright because they were relatively close to us. Of course, a star's apparent magnitude — the brightness we see from Earth — depends on both its intrinsic brightness and its distance.

It turns out that all three belt stars lie roughly 1,250 light-years from Earth, though keep in mind that distance determinations become less accurate the farther away a star resides. Even the European Space Agency's Gaia spacecraft, the best instrument we have for measuring stellar distances, has difficulty when it comes to bright objects.

For the belt stars to shine so brightly despite their vast distances, they must be intrinsically luminous. One way to compare stars with different distances and luminosities is to look at their absolute magnitudes — how bright they would appear at a standard distance of 10 parsecs (32.6 light-years).

Bearing in mind slight uncertainties, all three belt stars would appear bright enough to see in daylight if they were just 10 parsecs away. Mintaka would shine around magnitude –4.4 while Alnitak would come in at magnitude –6.0 and Alnilam would beat them both at magnitude –6.4.

Of the three belt stars, Alnilam is the only one without a companion. Mintaka is a multiple system with five components, although only one, a 7th-magnitude object nearly 1' away, is easy to see through a small telescope. Alnitak is a triple system. Its two bright components form a lovely but somewhat challenging double for small scopes. The stars shine at magnitudes 1.9 and 4.0 with just 2.4" separating them.

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 30° south latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

9 P.M. April 1
8 P.M. April 15
7 P.M. April 30

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

STAR MAGNITUDES

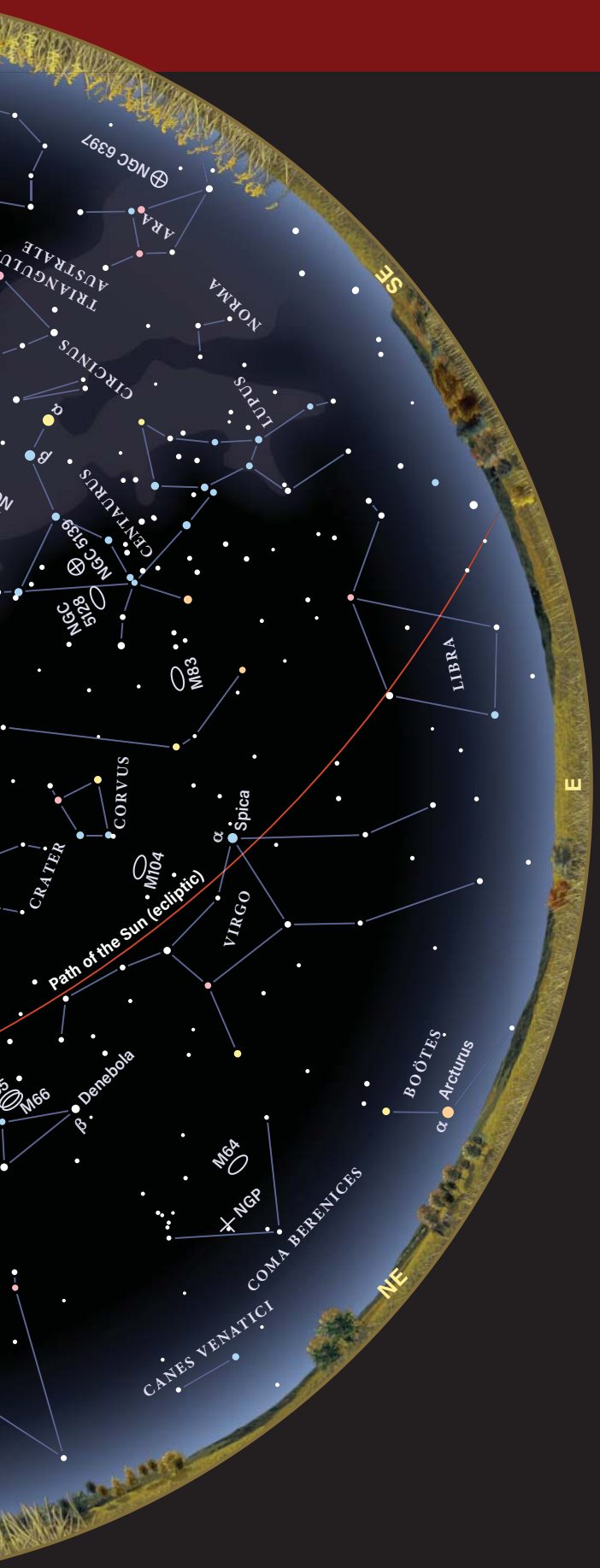
- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**



APRIL 2026

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

2 Full Moon occurs at 2h12m UT

3 Mercury is at greatest western elongation (28°), 23h UT

6 The Moon passes 0.6° south of Antares, 20h UT

7 The Moon is at apogee (404,970 kilometers from Earth), 8h31m UT

10 Last Quarter Moon occurs at 4h52m UT

13 Mars passes 0.3° north of Neptune, 10h UT

15 The Moon passes 5° north of Mercury, 19h UT

The Moon passes 4° north of Neptune, 21h UT

16 The Moon passes 4° north of Mars, 1h UT

The Moon passes 5° north of Saturn, 6h UT

Mercury passes 1.4° south of Neptune, 16h UT

17 New Moon occurs at 11h52m UT

19 The Moon is at perigee (361,630 kilometers from Earth), 6h56m UT

The Moon passes 5° north of Venus, 9h UT

The Moon passes 5° north of Uranus, 18h UT

20 Mercury passes 1.8° south of Mars, 0h UT

Mercury passes 0.5° south of Saturn, 8h UT

Mars passes 1.3° north of Saturn, 18h UT

22 Lyrid meteor shower peaks

The Moon passes 4° north of Jupiter, 22h UT

24 First Quarter Moon occurs at 2h32m UT

Venus passes 0.8° north of Uranus, 5h UT

26 The Moon passes 0.2° north of Regulus, 1h UT

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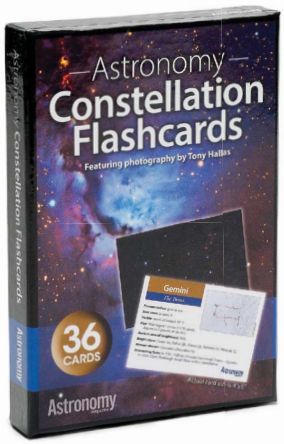

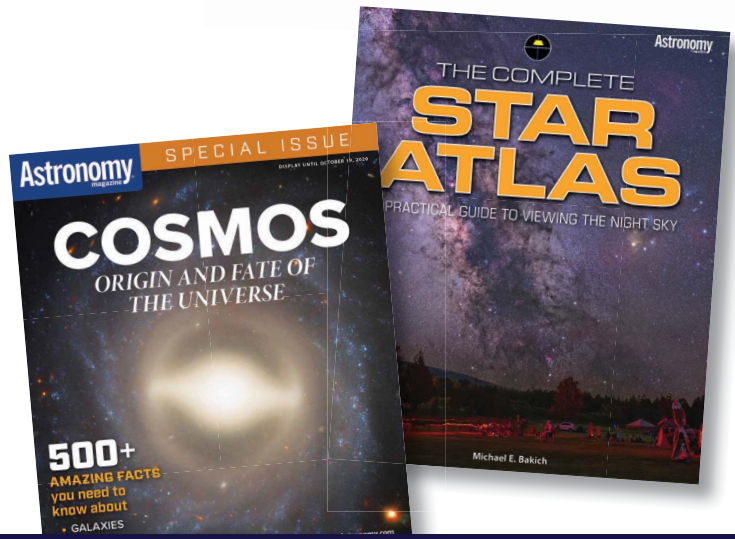

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